FREEZING AND IRRADIATION OF FISH

Freezing and Irradiation of Fish

Edited by

RUDOLF KREUZER

Published by
Fishing News (Books) Limited
Ludgate House, 110 Fleet Street,
London, EC4, England

© FAO 1969

The copyright in this book is vested in the Food and Agriculture Organization of the United Nations, for which Fishing News (Books) Ltd. acts as publisher. The book may not be reproduced, in whole or in part, by any method or process, without written permission from the copyright holder. Applications for such permission, with an outline of the purpose and extent of the reproduction desired, should be addressed to: The Director, Publications Division, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100, Rome, Italy.

The views expressed in this book are those of the contributors

Editorial Team

Associate Editor:	**R. S. Bolton**
Technical:	**A. A. da Costa**
	H. Lisac
Translation:	**C. González Manero**
	M. Lindemann
Drawings:	**M. G. Cassola**

Made and Printed in Great Britain by
The Whitefriars Press Ltd., London and Tonbridge

Contents

Page No.

LIST OF CONTRIBUTORS . . . ix

PREFACE xv

NOTE FROM THE PRESIDENT OF THE CONFERENCE xvii

Part I—Freezing Fish at Sea

TECHNIQUES AND EQUIPMENT FOR FREEZING FISH AT SEA

Evaluation of Modern Techniques and Equipment for Freezing Whole Fish at Sea *M. B. F. Ranken* 1

Freezing Fillets at Sea . *W. Flechtenmacher* 24

Discussion 29

FACTORS AFFECTING QUALITY OF SEA FROZEN FISH

Fish as a Raw Material for Freezing: Factors Influencing the Quality of Products Frozen at Sea . . . . . *N. R. Jones* 31

Condition of Fish and its Influence on the Quality of the Frozen Product *R. M. Love* 40

Quality of Frozen Fish Fillets Influenced by the Freezing Process on Board Factory Vessels and the Cold Storage Ashore . *V. Meyer, N. Antonacopoulos and W. Flechtenmacher* 46

Condition of Newfoundland Offshore Fish and its Influence on Quality after Single and Double Freezing *W. A. MacCallum, June I. Jaffray, Dorothy A. Chalker and D. R. Idler* 56

Discolouration in Sea-Frozen Fish Fillets *T. R. Kelly* 64

Quality of Sea Frozen Fish from the North-eastern Pacific Ocean *N. Tomlinson, Shirley E. Geiger and S. W. Roach* 68

Influence of Timelag Prior to Freezing on the Quality of Redfish . *D. J. Tilgner and W. Rogoś* 76

Discussion 77

FREEZING MEDIA

Design of Systems for Freezing Tuna at Sea *J. W. Slavin and R. Finch* 80

La congélation du poisson par immersion dans une saumure de chlorure de calcium *P. Dalcq* 85

A Seagoing Fish Processing and Liquid Nitrogen Generation System *F. Breyer, R. C. Wagner and J. Seliber* 91

Freezing Rates of Seafoods as Influenced by Heat Transfer Coefficients of Liquid Refrigerants *D. W. Baker and S. E. Charm* 94

Discussion 98

Page No.

SUPERCHILLING

Superchilling Fish—A Review *C. J. Carlson* 101

The Chemical and Physical Characteristics of Cod Stored at Superchill Temperatures *H. E. Power, Margaret L. Morton and Ruth E. Sinclair* 104

Partial Freezing of Pacific Salmon Intended for Canning *S. W. Roach and N. Tomlinson* 114

Anomalous Behaviour of Frozen Cod Muscle Stored Near its Melting Point *R. M. Love* 119

Discussion 124

Part II—Freezing and Processing Frozen Fish

PHYSICAL EFFECTS OF FREEZING FISH

Aspects physiques de la congélation des poissons *A. Gac* 129

Influence of Freezing and Cold Storage on the Submicroscopical Structure of Fish Muscle *A. Liljemark* 140

Discussion 145

SPECIFIC PROBLEMS AND TECHNIQUES IN FREEZING FISH

Freezing of Shellfish *P. Hansen and J. Aagaard* 147

A Comparison of the Quality of Frozen Plaice Fillets Prepared from Fresh or Frozen Raw Materials . . . . . *P. Hansen* 159

Discolouration of Tuna Meat and Red-skin Fish During Frozen Storage *K. Amano, M. Bito and N. Tsukuda* 161

Discussion 165

THE EFFECT OF POLYPHOSPHATE TREATMENT

Effect of Brining and Polyphosphate on Yield and Quality . . . *W. J. Dyer* 167

Polyphosphate Treatment of Cod Muscle *A. H. Sutton* 172

(with addendum by A. H. Sutton and J. I. W. Anderson—Bacterial contamination of fillets due to polyphosphate dipping)

Discussion 176

FREEZING OF TROPICAL FISH

Freezing of Tropical Fish . *A. N. Bose* 179

(with addendum—Refrigerated sea water in the preservation of tropical fish)

Factors Influencing Quality of Frozen Fish at Sea in Subtropical and Tropical Areas *E. Kordyl and Z. Karnicki* 189

Discussion 194

Page No.

THAWING FROZEN FISH

Evaluation of Techniques and Equipment for Thawing Frozen Fish . *J. H. Merritt* 196

Thawing of Frozen Fish in Water *M. R. Hewitt* 201

Essai d'application de la méthode de décongélation électronique à la sardine congelée destinée à la conserve *J. R. Crépey et D. Mairey* 206

Influence of Thawing and Thawing Methods on the Immediate and Refrozen Storage Quality of Fish *W. A. MacCallum and D. R. Idler* 213
(with addendum by H. C. Freeman and D. R. Idler—Green discolouration in flounder)

Discussion 222

Part III—Economics of Producing and Marketing Frozen Fish Products

THE FUTURE OF THE SHORE-BASED FREEZING INDUSTRY

Specific Problems and Techno-economic Considerations in the Shore-based Fish Freezing Industry . . . . . *E. Heen* 225

Discussion 229

ECONOMIC FACTORS AFFECTING THE FISH FREEZING INDUSTRY

Economic Considerations in the Production of Frozen Fish and its Marketing and Distribution . . . *E. S. Holliman* 231

Economic Appraisal of Different Freezing Methods . . . . *C. L. Rasmussen* 233

Commercial Aspects of Reprocessing and Marketing Sea Frozen Fish *W. A. MacCallum and K. Šepić* 240

Economics of Frozen Fish Marketing *J. A. Crutchfield* 252

Modern Distribution of Frozen Fish Products *E. Petersen* 256

Discussion 261

ECONOMIC CONSIDERATIONS IN THE DEVELOPING FISH FREEZING INDUSTRIES

Primeras Experiencias en la Congelación y Mercadeo de Filetes de Pescado en Peru *J. Basadre* 265

Le développement de la congélation en mer et à terre et de la consommation du poisson congelé dans les pays tropicaux de l'Ouest africain . . *R. A. Moal et J. Gousset* 268

Discussion 280

Page No.

PRODUCT DEVELOPMENT

Role of Product Development in the Rational Utilization of Fishery Resources, with Particular Reference to Freezing Fish at Sea *R. Kreuzer* 282

New Product Development—A Conceptual Approach . . . . *J. C. O'Sullivan* 289

New Product Development . *P. F. C. Sale* 295

Product Development and Vacuum Packaging Technique . . . *J. Aagaard* 299

Development of Fish Products with Particular Reference to Frozen Minced Fish Muscle (Surimi) *E. Tanikawa, T. Motohiro and M. Akiba* 304

Effect of Sodium Citrate on the Keeping Quality of Frozen Surimi (Frozen Fish Paste) *M. Okada* 312

Discussion 314

Part IV—The Quality of Frozen Fish Products and its Assessment

FACTORS INFLUENCING QUALITY OF FROZEN FISH PRODUCTS

Factors Influencing Quality Changes During Frozen Storage and Distribution of Frozen Products, Including Glazing, Coating and Packaging *W. J. Dyer and J. Peters* 317

Changes in the Eating Quality of Frozen Stored Cod and Associated Chemical and Physical Changes . . . . *J. J. Connell* 323

Factors Affecting the Texture of Frozen Fish *Kirsteen O. Kelly* 339

Rate of Survival of Organisms of Sanitary Significance During Freezing and Subsequent Storage *A. Lekshmy, D. R. Choudhuri and V. K. Pillai* 343

Discussion 348

QUALITY ASSESSMENT

Quality Control of Frozen Fish in Modern Fish Industries . . . *H. Jendrusch* 353

Evaluation of Quality of Frozen Fish and Fish Portions . . . . *U. Kietzmann* 358

A Taste Panel Technique for Evaluating the Eating Quality of Frozen Cod *C. R. Baines, J. J. Connell, D. M. Gibson, P. F. Howgate, Evelyn I. Livingston and J. M. Shewan* . . 361

Estimation of Hypoxanthine Concentrations in Fish Muscle by a Rapid, Visual Modification of the Enzymatic Assay Procedure *J. R. Burt, G. D. Stroud and N. R. Jones* . . . 367

Objective Measurement of the Hardness Parameter in Cooked Fish Muscle *A. H. Sutton and G. Main* 371

Page No.

Use of Ultra-violet Light for Determining whether Fresh or Frozen Fish Has Passed through *Rigor Mortis* . *H. Wittfogel* 376
Discussion 377

Part V—Storage, Packaging and Distribution of Frozen Fish Products

DESIGN AND OPERATION OF COLD STORES

Design and Operation of Cold Stores for Fishery Products . *G. Lorentzen* 381
Trends in Building Design, especially Prefabricated Section Construction *P. O. Persson* 391
La protection des isolations contre la pénétration de la vapeur d'eau *P. Clément* 395
Discussion 398

PACKAGING AND DISTRIBUTION OF FROZEN FISH PRODUCTS

Envasado de Pescado Congelado *L. Sicre* 401
Experience with Modern Packaging *C. A. Almarker* 406
State of the Art and Problems of Frozen Fish Packaging . . . . *R. Heiss* 409
Transport of Frozen Fish . *M. A. Foley* 414
Discussion 421

Part VI—Preservation of Fishery Products by Irradiation

THE QUALITY ASPECTS OF SEAFOOD IRRADIATION

Quality Indices that can be used to Assess Irradiated Seafoods *J. Spinelli, G. Pelroy and D. Miyauchi* 425
Quality Assessment and Consumer Acceptance of Irradiated Seafoods *J. M. Shewan and G. Hobbs* 431
Pruebas de Radurización de Filetes de Pescado Fresco y de Arenques Ahumados Conservados a Diferentes Temperaturas *D. de la Sierra Serrano* 434

Page No.

Effect of Irradiation on the Keeping Quality of Packaged Cod Flesh *J. van Mameren, K. J. A. van Spreekens, H. Houwing and D. A. A. Mossel* . . 446
Preliminary Experiments on the Use of Irradiation to Destroy Enteropathogenic Bacteria on Freshwater Fish *D. A. A. Mossel and K. J. A. van Spreekens* 449
Effect of Irradiation on *Anisakis* Larvae in Salted Herring *J. van Mameren and H. Houwing* 451
Irradiation Inactivation of Food Infection Microorganisms in Seafoods *A. W. Anderson* 454
Effects of Multiple Dose Irradiation on the Bacterial Flora of Seafoods *J. Liston, A. M. Dollar and J. R. Matches* 463
Irradiation Cleavage of Trimethylamine Oxide in Fish Muscle *K. Amano and H. Tozawa* 467
Complementary Effect of Food Preservative and Gamma Radiation Treatment of Whale and Horse Mackerel Flesh *T. Tomiyama, S. S. Jeng, E. Shiraishi, M. Hamada and Y. Yamada* . . . 472
Discussion 476

PRESENT STATUS AND CONSIDERATIONS REGARDING WHOLESOMENESS

Status of Legislation on Irradiated Food *H. E. Goresline* 478
Status of Research on Irradiated Fish and Shellfish in the United States *L. J. Ronsivalli, J. D. Kaylor and J. W. Slavin* 482
Present Status of Radiation Preservation of Fish and Fishery Products in Europe *G. Hobbs and J. M. Shewan* 488
Irradiación de Productos de la Pesca—Posibilidades Españolas *D. de la Sierra Serrano* 495
L'expérience italienne dans le secteur de la radiopasteurisation des produits de la pêche *D. Massa et A. Perna* 499
Discussion 501

ECONOMIC ASPECTS AND PRODUCTION TECHNOLOGY

Economic Feasibility of Radiopasteurization of Fish . . . *L. W. van Meir* 504
Irradiation of Fish at Sea *J. H. Carver, T. J. Connors and J. W. Slavin* 509
Meat Colour Regeneration in Frozen Tuna by Irradiation *K. Amano and H. Yamanaka* 514
Discussion 516

List of Contributors

Figures in bold type denote page number on which author's paper appears

AAGAARD, J. A. . . . **147**, 166, 177, **299**
Scientific Officer, Technological Laboratory, Ministry of Fisheries, Øster Voldgade 10, Copenhagen K, Denmark.

AKIBA, Dr. M. **304**
Laboratory of Marine Food Technology, Faculty of Fisheries, Hokkaido University, Hokodate, Hokkaido, Japan.

ALMARKER, C. A. **406**
Director, Marketing Department, AB Akerlund Rausing, Lund 1, Sweden.

ALVAREZ DE MENESES, A. 350
Oceanógrafo, Institute Español de Oceanografía, Alcalá 27, Madrid, España.

AMANO, Dr. K. **161**, 166, **467**, 476, **514**, 518, 519
Chief, Fish Preservation Division, Tokai Regional Fisheries Research Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, 5–5 Kachidoki, Chuo-ku, Tokyo.

ANDERSON, A. W. 351, **454**
Oregon State University, Corvallis, Oreg., U.S.A.

ANDERSON, J. I. W. **176**
Unilever Research Laboratory (Colworth), Greyhope Road, Aberdeen, Scotland, U.K.

ANTONACOPOULOS, Dr. N. **46**
Institute for Biochemistry and Technology, Bundesforschungsanstalt für Fischerei, Hamburg, Federal Republic of Germany.

BAINES, C. R. **361**
Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

BAHR, Dr. K. 261, 421
Ministerialrat, Bundesministerium für Ernährung, Landwirtschaft und Forsten, 53 Bonn, Federal Republic of Germany.

BAKER, D. W. **94**
Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Mass. 01931, U.S.A.

BANKS, Dr. A. . . . 78, 229, 348, 350, 378, 399
Deputy Director, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

BASADRE, J. **265**
Director, Sociedad Nacional de Pesquería, Productos Marinos S.A. Azangaro 235, 2° Piso, Apartado 646, Lima, Perú.

BERSAMIN, Dr. S. 501
Chief Fishery Technologist, Utilization Division, Philippine Fisheries Commission, Intramuros, Manila, Philippines.

BITO, M. **161**
Tokai Regional Fisheries Research Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, 5–5 Kachidoki, Chuo-ku, Tokyo.

BLIGH, Dr. E. G. 315, **380**
Scientific Leader, Technological Section, Freshwater Institute, Fisheries Research Board of Canada, 501 University Crescent, Winnipeg 19, Man., Canada.

BOSE, Dr. A. N. 179
Director, Central Institute of Fisheries Technology, Ernakulam 1, Kerala State, India.

BRAMSNAES, Professor F. 422
Director, Department of Technical Biochemistry II, Technical University of Denmark, Øster Voldgade 10, Trappek, Copenhagen K, Denmark.

BREYER, F. **91**
Executive Vice-President, Integral Process Systems, Inc., 5423 North Milton Parkway, Rosemont, Ill. 60018, U.S.A.

BURT, Dr. J. R. 79, **367**
Senior Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

BUTCHER, L. G. B. 261, 263
Principal Administrator, Fisheries Division, Organization for Economic Cooperation and Development (OECD), 94 rue Chardon Lagache, Paris 16e.

CARLSON, C. J. **101**, 124
Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Mass. 01931, U.S.A.

CARVER, J. H. **509**
Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Mass. 01931, U.S.A.

CHALKER, Dorothy A. **56**
Technological Unit, Fisheries Research Board of Canada, St. John's, Nfld., Canada.

CHARM, Professor S. E. . . . **94**, 476, 502
Scientific Director, New England Enzyme Center, Tufts University School of Medicine, Boston, Mass. 02111, U.S.A.

CHOUDHURI, D. R. **343**
Central Institute of Fisheries Technology, Ernakulam-1, Kerala State, India.

CLÉMENT, P. **395**
Directeur, Société d'Etudes Techniques Industrielles et Frigorifiques, 17 rue de Clichy, Paris 9e.

CONNELL, Dr. J. J. . 145, 146, **323**, 349, 350, **361**, 378
Principal Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

CONNORS, T. J. **509**
Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Mass. 01931, U.S.A.

COSTA, Dr. C. F. 127
Administrador técnico, Companhia Portuguesa de Pesca, Av. 24 de Julho, 3–2°, Lisboa, Portugal.

Page No.

CRÉPEY, Dr. J. R. 30, **206**
Maître de recherches, Institut scientifique et technique des pêches maritimes, 59 Avenue Raymond Poincaré, Paris 16e.

CRUTCHFIELD, J. A. **252**
Department of Economics, University of Washington, Seattle, Wash. 98105, U.S.A.

DALCQ, Dr. P. R. L. A. **85**
Ingénieur en Chef, Division Produits Chimiques, Service Technico-Commercial, S.A. Solvay et Cie, 33 rue Prince Albert, Bruxelles 5, Belgique.

DANIELSEN, B. H. 230, 314, 351
Findus International SA, Case Postale 22, Châtel St. Denis, Fribourg, Switzerland.

DARGHOUTH, M. A. 166, 262
Ingénieur Principal, Chef du Service des Industries alimentaires, Division de la Production industrielle, Sous-Secrétariat d'Etat á l'Industrie et au Commerce, 195 rue de la Kasbah, Tunis, Tunisie.

DIEHL, Professor J. F. 502
Director, Bundesforschungsanstalt für Lebensmittelfrischhaltung, Engesserstrasse 20, 75 Karlsruhe, Federal Republic of Germany.

DOLLAR, Dr. A. M.. . . . . **463**
State of Hawaii, Department of Agriculture, 1428 S King St., P.O. Box 5425, Honolulu, Hawaii 96814, U.S.A.

DYER, Dr. W. J. . . . 77, **167**, **317**, 349, 378, 379
Biochemist, Technological Research Laboratory, Fisheries Research Board of Canada, P.O. Box 429, Halifax, N.S. Canada.

EARLY, J. C. 352
Bacteriologist, Senior Scientific Officer, Humber Laboratory, Ministry of Technology, Wassand Street, Hull, Yorkshire, U.K.

FERNANDEZ Y FERNANDEZ, A. . . . 229, 262, 264
Project Manager, UNDP/SF Fisheries Development Project, Casilla 288, Mar del Plata, Argentina.

FINCH, R. **80**
Laboratory Director, Technological Laboratory, Bureau of Commercial Fisheries, Terminal Island, Cal. 90731, U.S.A.

FLECHTENMACHER, W. **24**, 29, **46**
Refrigeration and Processing Technique, Institute for Biochemistry and Technology, Bundesforschungsanstalt für Fischerei, Palmaille 9, 2 Hamburg 50, Federal Republic of Germany.

FOLEY, M. A. 378, 398, **414**
Chief Engineer, Inspection Service, Department of Fisheries, Ottawa 8, Ont., Canada.

FREEMAN, H. C. 221
Technological Research Laboratory, Fisheries Research Board of Canada, P.O. Box 429, Halifax, N.S., Canada.

GAC, Dr. A. **129**
Ingénieur en chef, Centre National d'Etudes Techniques et de Recherches Technologiques pour l'Agriculture, les Forêts et l'Equipement Rural, Parc de Tourvoie, Antony (Seine), France.

GALLIVER, Dr. G. 315
Research Manager, Unilever Research Laboratory, Colworth House, Sharnbrook, Bedford, U.K.

GARCIA GARCIA, Dr. J. C. 30
Director de Factoria, Pescanova S.A., Chapela, Vigo, España.

GEIGER, Shirley E. **68**
Technological Research Laboratory, Fisheries Research Board of Canada, 6640 N.W. Marine Drive, Vancouver B.C., Canada.

GIBSON, D. M. **361**
Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

GORESLINE, Dr. H. E. **478**, 502
Food Irradiation Specialist, Food Preservation Section, Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture, International Atomic Energy Agency, Kärntnerring 11–13, 1010 Vienna, Austria.

GOUSSET, Dr. J. **268**
Services vétérinaires, Ministère de l'Agriculture, 3 rue Barbet de Jouy, 75—Paris 7e.

GUILLOT, Dr. G. 350, 501
Conseiller Scientifique, Compagnie des Entrepôts et Gares Frigorifiques, 42 rue du Louvre, Paris 1e.

HAMADA, M. **472**
Faculty of Agriculture, Kyushu University, Hakozaki-machi, Fukuoka, Japan.

HANSEN, P. **147**, **159**, 222, 315, 476
Director, Technological Laboratory, Ministry of Fisheries, Øster Voldgade 10, Copenhagen K, Denmark.

HARRISON, R. W. 264, 422
Director, Fishery Economics and Products Division, Food and Agriculture Organization of the United Nations, Rome, Italy.

HEEN, Dr. E. . . . 79, **225**, 230, 261, 315, 399, 502
Director, Norwegian Fisheries Research Institute, P.O. Box 187, Bergen, Norway.

HEISS, Professor R. **409**
Institut für Lebensmitteltechnologie und Verpackung E.V., Schragenhofstrasse 35, 8 München 50, Federal Republic of Germany.

HEWITT, M. R. 29, **201**
Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

HOBBS, Dr. G. **431**, **488**, 518
Bacteriologist, Senior Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

VAN HOECK, F. 503
Biology Division (Research and Teaching), Euratom, 51–53 rue Belliard, Bruxelles, Belgium.

HOLLIMAN, E. S. **231**, 261, 263
Chief, Fishery Economics and Development Branch, Fishery Economics and Products Division, Food and Agriculture Organization of the United Nations, Rome, Italy.

Page No.

HOLSTON, J. A. 98, 378, 477
Laboratory Director, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Mass. 01931, U.S.A.

HOUWING, H. **446, 451**
Deputy Director, Institute for Fishery Products TNO, Haringkade 1, Ijmuiden, Netherlands.

HOWGATE, P. F. 145, **361**
Experimental Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

IDLER, Dr. D. R. **56, 213,** 221
Laboratory Director, Technological Research Laboratory, Fisheries Research Board of Canada, P.O. Box 429, Halifax, N.S., Canada.

JAFFRAY, June I. **56**
Technological Unit, Fisheries Research Board of Canada, St. John's, Nfld., Canada.

JENDRUSCH, H. **353**
Bacteriologist, Central Laboratory, "Nordsee" Deutsche Hochseefischerei GmbH, Klussmannstrasse 3, 285 Bremerhaven-G, Federal Republic of Germany.

JENG, S. S. **472**
Faculty of Agriculture, Kyushu University, Hakozaki-machi, Fukuoka, Japan.

JONES, Dr. N. R. . **31,** 77, 78, 79, 195, 349, **367,** 379
Chief, Food Science and Technology Department, Tropical Products Institute, 56/62 Gray's Inn Road, London, W.C.1.

KARNICKI, Z. **189**
Fish Processing Technologist, Sea Fisheries Institute, Al. Partyzantow 34/13, Gdynia, Poland.

KAYLOR, J. D. **482**
Bureau of Commercial Fisheries, Department of the Interior, Washington, D.C., 20240, U.S.A.

KELLY, Kirsteen O. **339**
Research Biochemist, Unilever Research Laboratory (Colworth), Greyhope Road, Torry, Aberdeen, Scotland, U.K.

KELLY, Dr. T. R. . . **64,** 78, 126, 349, 350, 379
Unilever Research Laboratory (Colworth), Greyhope Road, Torry, Aberdeen, Scotland, U.K.

KIETZMANN, Dr. U.. . . . . **358**
Staatliches Veterinäramt, Bremerhaven, Federal Republic of Germany.

KORDYL, E. **189**
Chief, Technological Section, Sea Fisheries Institute, Al. Zjednoczenia 1, Gdynia, Poland.

KOVACS, Dr. A. S. 378, 421, 502
Central Laboratory, Grosseinkaufs-Gesellschaft Deutscher Konsumgenossenschaften mbH, Besenbinderhof 52, 2 Hamburg 1, Federal Republic of Germany.

KREUZER, Dr. R. . . . 28, 29, 99, 263, 280, **282** 316, 348, 519
Chief, Fishery Products and Marketing Branch, Fishery Economics and Products Division, Food and Agriculture Organization of the United Nations, Rome, Italy.

Page No.

LEKSHMY, Dr. A. **343**
Central Institute of Fisheries Technology, Ernakulam-1, Kerala State, India.

LILJEMARK, A. **140,** 146
Head of Electron Microscopy Laboratory, Swedish Institute for Food Preservation Branch, Kallebäck, Göteberg S, Sweden.

LISTON, Professor J. 316, **463,** 476, 477, 502, 518, 519
Head, Food Science Department, College of Fisheries, University of Washington, Seattle, Wash. 98105, U.S.A.

LITTLE, Dr. W. T. . . . 29, 79, 176, 229, 378, 421
Research Manager, Unilever Research Laboratory (Colworth), Greyhope Road, Torry, Aberdeen, Scotland, U.K.

LIVINGSTON, Evelyn I. **361**
Experimental Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

LLOYD, B. J. 263
U.N.S.A. Observer, Department of Microbiology, Reading University, Reading, Berkshire, U.K.

LORENTZEN, Professor G. . **381,** 399, 400, 422
Institute of Refrigeration Techniques, Technical University of Norway, Trondheim, Norway.

LOVE, Dr. R. M. . 29, **40,** 77, **119,** 122, 177, 348, 349
Principal Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

MACCALLUM, W. A. . **56,** 78, 177, **213,** 223, **240,** 349, 351, 379
Chief, Technological Unit, Fisheries Research Board of Canada, St. John's, Nfld., Canada.

MAIN, G. **371**
Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

MAIREY, Dr. D. **206**
Ingénieur de recherches, Institut scientifique et technique des pêches maritimes, 59 Avenue Raymond Poincaré, Paris 16e.

MALICK DIA, Dr. I.. . . . . 280, 379
Chef de la Production des Pêches, Service de l'Océanographie et des Pêches Maritimes, Ministère de l'Economie Rurale, BP 289, Dakar, Sénégal.

VAN MAMEREN, Dr. J. **446, 451**
Director, Institute for Fishery Products TNO, Haringkade 1, Ijmuiden, Netherlands.

MASSA, Dr. D. . . . 316, **499,** 502, 519,
Veterinario Provinciale, Direzione Generale Servizi Veterinari, Ministero della Sanità, EUR, Rome, Italie.

MATCHES, J. R. **463**
Research Assistant Professor, Food Science Department, College of Fisheries, University of Washington, Seattle, Wash. 98105, U.S.A.

VAN MEIR, L. 261, **504,** 519
Assistant Director for Economics, Bureau of Commercial Fisheries, Department of the Interior, Washington, D.C. 20240, U.S.A.

Page No.

MERRITT, J. H. . . . 125, **196**, 222, 399, 422
Engineer, Principal Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

MEYER, Professor V. **46**, 229
Director, Institute for Biochemistry and Technology, Bundesforschungsanstalt für Fischerei, Palmaille 9, 2 Hamburg 50, Federal Republic of Germany.

MICHON, Dr. G. 476
Secrétaire Permanent, Commission Interministerielle des Radioéléments, BP 8, Gyf/Yvette, France.

MIYAUCHI, D. **425**
Bureau of Commercial Fisheries Technological Laboratory, 2725 Montlake Boulevard East, Seattle, Wash. 98102, U.S.A.

MOAL, Dr. R. A. **268**
Chef du Département pêches, S.C.E.T. Cooperation, 5–7 rue Bellini, 92 Puteaux, France.

MORTON, Margaret L. **104**
Technological Research Laboratory, Fisheries Research Board of Canada, P.O. Box 429, Halifax, N.S., Canada.

MOSSEL, D. A. A. **246, 449**
Central Institute for Nutrition and Food Research TNO, Zeist, Netherlands.

MOTOHIRO, Dr. T. **304**
Laboratory of Marine Food Technology, Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

OKADA, M. **312**
Tokai Regional Fisheries Research Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, Tsukishima, Chuo-ku, Tokyo.

O'SULLIVAN, J. C. . . . 263, **289**, 352, 422
General Development Manager, Irish Sea Fisheries Board, Hume House, Ballsbridge, Dublin 4, Ireland.

PACE, Dr. W. 501, 502, 503
Technical Representative (Food Irradiation), Biology Branch, Division of Biology and Medicine, U.S. Atomic Energy Commission, Washington, D.C. 20545, U.S.A.

PELROY, G. **425**
Bureau of Commercial Fisheries Technological Laboratory, 2725 Montlake Boulevard East, Seattle, Wash. 98102, U.S.A.

PEREZ GARCÍA, Dr. T. 166
Profesor, Facultad Veterinaria, Instituto de Biología Animal, Madrid, España.

PERNA, Dr. A. **499**
Assistent ordinaire, Istituto Sperimentale per l'Igiene ed il Controllo Veterinario dei prodotti della Pesca, Via R. Paolucci, Pescara, Italie.

PERSSON, P. O. **391**, 399, 400
Managing Director, Frigoscandia AB, Box 214, Landskronavägen 11, Helsingborg, Sweden.

PETERS, J. A. 124, **317**
Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Mass. 01931, U.S.A.

Page No.

PETERSEN, E. **256**
Frionor Norsk Frossenfisk A/L, Drammensvein 20, Oslo 2, Norway.

PILLAI, Dr. V. K. **343**
Central Institute of Fisheries Technology, Ernakulam-1, Kerala State, India.

POWER, H. E. **104**
Technological Research Laboratory, Fisheries Research Board of Canada, P.O. Box 429, Halifax, N.S., Canada.

RANKEN, Commander M. B. F. . **1**, 29, 125, 223 261, 263,
3 Redlynch Court, 70 Addison Road, London W.14.

RASMUSSEN, C. L. **233**
Industrial Analyst, Western Regional Research Laboratory, U.S. Department of Agriculture, 800 Buchanan Street, Albany, Cal. 94710, U.S.A.

REAL, GÓMEZ, G. 502
Representante del Código Alimentario Español, Escuela Nacional de Sanidad, Ciudad Universitaria, Madrid, España.

ROACH, S. W.. . . . . **68, 114**, 399
Research Engineer, Technological Research Laboratory, Fisheries Research Board of Canada, 6640 N.W. Marine Drive, Vancouver 8, B.C., Canada.

ROGOŚ, W. **76**
Department of Animal Products Technology, Faculty of Chemistry, Politechnika Gdańska Gdańsk 6, Poland.

RONSIVALLI, L. J. **482**
Bureau of Commercial Fisheries, Department of the Interior, Washington, D.C. 20240, U.S.A.

RUDOLPHI, E. G. 29, 262, 518, 519
Managing Director, Firma F. Schottke, 285 Bremerhaven-G, Federal Republic of Germany.

SALE, P. F. C. **295**, 316, 352
Product Group Development Manager, Central Development Department, Birds Eye Foods Limited, South Denes, Great Yarmouth, Norfolk, U.K.

SCARLATTI, E.. 126
Engenheiro Naval, Avenida 24 de Julho 60–2°, Lisboa, Portugal.

SCOTT, Professor J. K. 351
Professor of Food Technology, Massey University, Palmerston North, New Zealand.

SELIBER, J. **91**, 100, 281
Manager, Technical Projects, Integral Process Systems Inc., 5423 North Milton Parkway, Rosemont, Ill. 60018, U.S.A.

ŠEPIĆ, K., Dipl. Eng. (Chem. Technology) **240**, 280
Leading Technologist, Center for Fish and Mediterranean Economy, Institute of Food Science and Technology, P.O. Box 110, Zadar, Yugoslavia.

SHEWAN, Dr. J. M. **361, 431, 488**
Senior Principal Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

SHIRAISHI, E. **472**
Faculty of Agriculture, Kyushu University, Hakozaki-machi, Fukuoka, Japan.

Page No.

SICRE-CANUT, Dr. L. **401**
Presidente, Instituto Español del Envase y Embalaje SA, Breton de los Herreros 67, Madrid 3, España.

SIDHU, Dr. G. S. 165, 476
Senior Research Scientist, Division of Food Preservation, CSIRO, P.O. Box 43, Ryde, New South Wales, Australia.

DE LA SIERRA SERRANO, D. . . **434**, 476, **495**
Aristoteles 9, (Barrio Blanco), Madrid 17, España.

SIMMONS, M. F. 379
Development Technologist, Fropax Eskimo Frood Ltd., Pelham Road, Cleethorpes, Lincolnshire, U.K.

SINCLAIR, Ruth E. **104**
Technical Research Laboratory, Fisheries Research Board of Canada, P.O. Box 429, Halifax, N.S., Canada.

SLAVIN, J. W. . . 29, **80**, 100, 229, 263, 352, 399, 422, 476, **482**, **509**
Assistant Director for Industrial Research, Bureau of Commercial Fisheries, Department of the Interior, Washington, D.C. 20240, U.S.A.

SOMMA, P. 399
Ingénieur Civil du Génie Maritime, 3 rue Rabelais, Paris 8e.

SØRENSEN, E. A. 352, 378
Factory Manager, Rahbekfisk, Fredericia, Denmark.

SOUDAN, Dr. F. 379
Chef du Service de Technologie et des Contrôles, Institut scientifique et technique des pêches maritimes, 59 Avenue Raymond Poincaré, Paris 16e.

SPIESS, W. E. L. 378
Head, Freeze-drying Laboratory, Bundesforschungsanstalt für Lebensmittelfrischhaltung, Engesserstrasse 20A, 75 Karlsruhe, Federal Republic of Germany.

SPINELLI, J. 380, **425**, 476
Research Chemist, Bureau of Commercial Fisheries Technological Laboratory, 2725 Montlake Boulevard East, Seattle, Wash. 98102, U.S.A.

VAN SPREEKENS, K. J. A. **446**, **449**
Institute for Fishery Products TNO, Haringkade 1, Ijmuiden, Netherlands.

STROUD, G. D. **367**
Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

SUBBA RAO, Dr. G. N. 194, 476
Fishery Officer, FAO Regional Office for Asia and the Far East, Maliwan Mansion, Bangkok, Thailand.

SUTTON, Dr. A. H. . . . **172**, 349, **371**, 380
Scientist, Unilever Research Laboratory (Colworth), Greyhope Road, Torry, Aberdeen, Scotland, U.K.

SYMONS, H. W. 348, 350, 351, 377, 378
Company Quality Controller, Birds Eye Foods Limited, Station Road, Walton-on-Thames, Surrey, U.K.

SZABO, A. 476
FAO/UNDP(TA) Fish Processing Expert, B.P. 138, Mopti, Mali.

TANIKAWA, Dr. E. **304**
Laboratory of Marine Food Technology, Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

Page No.

TEMPLETON, J. 78
Senior Scientific Officer, Torry Research Station, Ministry of Technology, 135 Abbey Road, Aberdeen, Scotland, U.K.

TILGNER, Professor D. J. **76**
Department of Animal Products Technology, Faculty of Chemistry, Politechnika Gdańska, Gdańsk 6, Poland.

TOMIYAMA, Dr. T. 77, 380, **472**, 476
Professor of Fishery Chemistry, Faculty of Agriculture, Kyushu University, Hakozaki-machi, Fukuoka, Japan.

TOMLINSON, Dr. N. **68**, **114**, 349, 350
Assistant Director, Technological Research Laboratory, Fisheries Research Board of Canada, 6640 N.W. Marine Drive, Vancouver 8, B.C., Canada.

TOZAWA, H. **467**
Tokai Regional Fisheries Research Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, 5–5 Kachidoki, Chuo-ku, Tokyo.

TSUKUDA, N. **161**
Tokai Regional Fisheries Research Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, 5–5 Kachidoki, Chuo-ku, Tokyo.

VARELA, Professor G. 377, 378
Catedrático Universidad de Granada, Laboratorio de Fisiologia Animal, Universidad de Granada, España.

VARGA, S. 350
Inspection Service, Department of Fisheries, Ottawa 8, Ont., Canada.

VIDAL, P. 501
Président-Directeur Général, Conservatome, 32 rue Thomassin, Lyon, France.

VYNCKE, W. 98, 166
Ingénieur Chimiste, Station de Recherches pour la Pêche Maritime, Hôtel de Ville (4éme étage), Ostende, Belgique.

WAGNER, R. C. **91**
Integral Process Systems Inc., 5423 North Milton Parkway, Rosemont, Ill. 60018, U.S.A.

WALTHER, H. J. 516
Departmental Manager, Leybold-Heraeus GmbH, Postfach 195, 5 Köln, Federal Republic of Germany.

WATANABE, K. 194, 280
Fishery Technologist (Processing), UNDP/SF Lake Kariba Fishery Research Institute, P.O. Box 110, Chilanga, Lusaka, Zambia.

WIESNER, Dr. L. 516, 519
Scientific Consultant, Euratom, 45 rue Belliard, Bruxelles, Belgium.

WITTFOGEL, Dr. H. **376**
Head, Nebenstelle Cuxhaven des Staatlichen Veterinäruntersuchungsamtes, Cuxhaven-F, Federal Republic of Germany.

YAMADA, Y. **472**
Faculty of Agriculture, Kyushu University, Hakozaki-machi, Fukuoka, Japan.

YAMANAKA, H. **514**
Tokai Regional Fisheries Research Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, 5–5 Kachidoki, Chuo-ku, Tokyo.

Preface

FISHERY resources are recognized as an important source of protein and the exploitation of their full potential for the lasting benefit of mankind is a challenge to all fishing nations. Fish now contributes about 10 per cent to the world's total animal protein intake. Since 1945 the world's fish catch has been increasing very rapidly, doubling about every 10–12 years. There is evidence that this increase can be maintained in the immediate future up to a limit, for the kinds of fish now being harvested, of around 100 to 200 million tons annually.

The fishery resources of the oceans, however, are not inexhaustible and their rational utilization can only be ensured if all nations concerned accept the idea that harvesting of the oceans has to be treated as a co-operative venture, and not merely a task for individual enterprises and single nations. Harvesting the sea without depleting the resources has extended beyond the national field and the countries concerned must work together to solve the problems involved in appraisal, management, conservation, exploitation and improvement of those fishery resources which are common property. In recognition of this, FAO has given top priority to improvement of international co-operation and the Organization's activities have been expanded to enable better co-ordination of international action in the development of world fisheries. There is an urgency to evaluate fish stocks in the different ocean areas as a basis for better management of heavily exploited resources and the more aggressive development of relatively untouched fish stocks. A particular problem in this respect concerns assistance to developing countries so that they may enter the high-seas fisheries and improve utilization of their inshore resources in a way which will be rewarding without depleting the stocks.

Technological advances, particularly in relation to preservation methods, have played an important role in the rapid development and effective utilization of fishery resources. The introduction of icing and freezing techniques promoted the large-scale expansion of the North Atlantic fishing industry and the growth of worldwide shrimp and tuna fisheries. In recent years, adaptation of methods and equipment enabling processing and freezing at sea has led to the construction of freezing vessels capable of large-scale exploitation of all oceans of the world. The increasing trend towards freezing at sea has created a need for developments in the technology of handling, storing and processing sea-frozen fish. In this respect, particular emphasis has been placed on methods for accelerated thawing, a necessary step in converting sea-frozen fish into consumer products. While freezing of fish has developed into the most attractive and widely-used modern method for the preservation of food fish, preservation by irradiation has reached a stage where its use on a commercial basis is believed to be technologically and economically feasible. It has potential use for extending the storage life of fresh fish, or as a supplementary process along with freezing. Irradiation offers promise in facilitating the utilization and distribution of fish and, in the future, may have great influence on the structure of some of our fishery industries. In preservation and processing technology, as in fish resource management and development, the combined efforts of scientists, engineers and technologists on both the national and international level is essential for the exchange of information and ideas to stimulate and co-ordinate research work and technological development.

It was with this idea in mind that the Technical Conference on the Freezing and Irradiation of Fish was planned and jointly organized with the International Institute of Refrigeration (IIR) and the International Atomic Energy Agency (IAEA), and held in conjunction with the XIIth International. Congress of Refrigeration in Madrid. The co-operation of these international organizations resulted in contributions by the foremost world authorities in all fields of refrigeration and in the field of irradiation of fish. Consequently, the proceedings of the Conference present an authoritative report on the freezing of fishery products, the storage and transportation of frozen fish and on the current status of the application of irradiation to the preservation of these commodities.

On behalf of FAO I should like to express my thanks to the Government of Spain, the IIR, the IAEA and to all of those who contributed to the success of the Conference and who made this book possible.

ROY I. JACKSON,
Assistant Director-General (*Fisheries*).

Food and Agriculture Organization,
Rome,
April 1969.

Presentación del Presidente de la Conferencia

LA feliz coincidencia de que la FAO, conjuntamente con el Instituto Internacional del Frío y el Organismo Internacional de Energía Atómica haya celebrado la Conferencia Técnica sobre Congelación e Irradiación del Pescado simultaneamente con el XII Congreso Internacional del Frío ha permitido reunir en un mismo edificio de Madrid a los mejores especialistas del mundo para estudiar las diversas técnicas del frío e irradiación al servicio de la humanidad para un mundo mejor.

La Dirección General de Pesca Marítima de mi país se siente muy honrada y satisfecha por la oportunidad que ha tenido de colaborar activamente en la organización y desarrollo de esta conferencia.

En ella se ha tratado de una manera concreta de la técnica del frío e irradiación para la conservación del pescado abarcando todos los eslabones de la cadena, es decir, desde el momento en que el pez llega a bordo del barco hasta que se encuentra ya servido en la mesa del consumidor. La trascendencia del tema no es preciso destacarla ya que todos estamos convencidos del papel fundamental que el pescado viene desempeñando, cada día en mayor grado, para el abastecimiento de proteínas a los pueblos. Recordaremos las cifras que probablemente están en la mente de todos.

En el año 1950 se capturaron en el mundo 20 millones de toneladas de pescado; en 1964, sólo catorce años después, se alcanzaron los 50 millones de toneladas. Se espera que en el año actual, 1967, se llegue a los 60 millones. Para el futuro se hacen previsiones de cifras que oscilan entre los 100 y los 200 millones de toneladas. Vemos, pues, el ritmo ascendente de las cosechas acuáticas fundamentalmente procedentes de los océanos y que se deben en una gran parte al desvelo y estudio de los hombres de ciencia de los distintos países, así como a las organizaciones internacionales implicadas en estos problemas. Se ocuparon en primer lugar los científicos de hacer un estudio sistemático para realizar el inventario de las especies más idóneas para su aprovechamiento y consumo. Posteriormente se prestó atención a un mejor conocimiento de su biología, así como de las condiciones físicas y químicas del medio en que habitan. Asimismo, entraron en el ámbito de la ciencia y de la técnica los sistemas de pesca, detección y localización del pescado, mecanización de mano de obra, comercialización y consumo, destacando rápidamente la atención al factor calidad. En toda esta labor han colaborado biólogos, químicos, físicos, estadísticos, industriales, hombres de la administración de pesquerías y más modernmanete, tecnólogos en general.

Hemos citado en mi opinión una palabra clave para esta Conferencia: me refiero a la "calidad". El gran problema es que el pescado resultaba un producto perecedero, se descomponía en un corto plazo, no podía almacenarse como el trigo y otros productos alimenticios, había que arrojarlo al mar a veces cuando se pescaba mucho para carecer de él cuando se pescaba poco, tal vez al día siguiente. Estas fluctuaciones resultaban perturbadoras para el consumidor que se veía privado de un alimento esencial, y trágicas para el pescador, ya que una buena pesca se veía malograda económicamente por la caída vertical de los precios.

Por otra parte, áreas oceánicas ricas en pescado resultaban inaccesibles para su explotación ya que las distancias impedían que el producto llegara a los mercados en buenas condiciones para el consumo.

La técnica del frío al servicio de la industria pesquera ha venido a recordar al mundo un problema trascendental al conseguir que el pescado haya dejado de ser un producto perecedero a corto plazo. Estas técnicas han permitido ampliar la gama de especies aprovechables para el consumo y aumentar sensiblemente las áreas de los océanos explotables permitiendo un desarrollo de la flota de pesca

de muchos países que han visto así incrementados sus recursos en beneficio de la dieta alimenticia de la población.

Refiriéndome más concretamenta a mi país, que es el caso que naturalmente conozco mejor, el consumo de pescado congelado era prácticamente desconocido en España hasta el año 1960. En el año 1961 se inició timidamente su consumo que escasamente alcanzó las 4.000 toneladas. El ritmo ha ido creciendo desde aquellas fechas habiendo sobrepasado el consumo en el año 1966 las 100.000 toneladas.

Respecto a la flota con instalaciones frigoríficas, España tenía en 1961 sólo ocho buques pesqueros con una capacidad de congelación diaria de 167 toneladas. En 1966, tenía ya en servicio 72 buques con instalaciones de congelación de una capacidad de 1.580 toneladas diarias. Cuenta, además, con una flota de 25 buques frigoríficos, adaptados para el transporte de pescado congelado. De la misma manera que los españoles, los habitantes de otros muchos pueblos están beneficiándose de la técnica del frío para enriquecer el nivel proteínico de su alimentación.

Asimismo, la irradiación, de la que personalmente tengo menos experiencia, está dejando de ser una promesa para convertirse en una auténtica realidad al servicio de la conservación del pescado.

Los trabajos y discusiones muy interesantes, sobre las diferentes facetas y aspectos de ambas técnicas contribuirán, sin duda a una autentica revolución en los sistemas para el mejor y más racional aprovechamiento de los recursos vivos acuáticos y cuyos beneficiosos resultados rebasarán problemente nuestras más optimistas esperanzas. Así lo espero para el bien de la humanidad.

IGNACIO DEL CUVILLO Y MERELLO
Presidente

PART I

FREEZING FISH AT SEA

TECHNIQUES AND EQUIPMENT FOR FREEZING FISH AT SEA

Evaluation of Modern Techniques and Equipment for Freezing Whole Fish at Sea . *M. B. F. Ranken*

Freezing Fillets at Sea . . . *W. Flechtenmacher*

Discussion

FACTORS AFFECTING QUALITY OF SEA FROZEN FISH

Fish as a Raw Material for Freezing: Factors Influencing the Quality of Products Frozen at Sea . *N. R. Jones*

Condition of Fish and its Influence on the Quality of the Frozen Product . . . . . *R. M. Love*

Quality of Frozen Fish Fillets Influenced by the Freezing Process on Board Factory Vessels and the Cold Storage Ashore
V. Meyer, N. Antonacopoulos and W. Flechtenmacher

Condition of Newfoundland Offshore Fish and its Influence on Quality after Single and Double Freezing
W. A. MacCallum, June I. Jaffray, Dorothy A. Chalker and D. R. Idler

Discolouration in Sea Frozen Fish Fillets . *T. R. Kelly*

Quality of Sea Frozen Fish from the North-eastern Pacific Ocean *N. Tomlinson, Shirley E. Geiger and S. W. Roach*

Influence of Timelag Prior to Freezing on the Quality of Redfish . . . *D. J. Tilgner and W. Rogoś*

Discussion

FREEZING MEDIA

Design of Systems for Freezing Tuna at Sea
J. W. Slavin and R. Finch

La congélation du poisson par immersion dans une saumure de chlorure de calcium . . . . . *F. Dalcq*

A Seagoing Fish Processing and Liquid Nitrogen Generation System . . *F. Breyer, R. C. Wagner and J. Seliber*

Freezing Rates of Seafoods as Influenced by Heat Transfer Coefficients of Liquid Refrigerants
D. W. Baker and S. E. Charm

Discussion

SUPERCHILLING

Superchilling Fish—A Review . . *C. J. Carlson*

The Chemical and Physical Characteristics of Cod Stored at Superchill Temperatures
H. E. Power, Margaret L. Morton and Ruth E. Sinclair

Partial Freezing of Pacific Salmon Intended for Canning
S. W. Roach and N. Tomlinson

Anomalous Behaviour of Frozen Cod Muscle Stored Near its Melting Point . . . . . *R. M. Love*

Discussion

Evaluation of Modern Techniques and Equipment for Freezing Whole Fish at Sea

by M. B. F. Ranken

Evaluation of modern techniques and equipment for freezing whole fish at sea

The concept of freezing whole fish at sea was based originally on reducing to a minimum the changes necessary in conventional trawlers compared with traditional icing methods. Latterly it has been concentrated on limiting the capital and running costs and crew problems associated with freezer vessels by leaving as much as possible of the preparation and processing operations involved to be done ashore, where they can be conducted much more economically and on a large scale. Unfortunately, vertical integration of the catching and shore processing and distribution sides of the industry has not proceeded far enough in some countries, so that whole fish freezing at sea is not always done in the way best suited to the market, although it may be the most economical purely from the owners' point of view.

The best methods of freezing whole fish at sea depend on numerous considerations including the fishing ground and climate, fish variety, type of vessel, port and shore processing facilities, distribution methods, consumer preferences, etc. Three basic methods of freezing exist: air-blast, contact and immersion. There are numerous variations of each of these and increasing ingenuity is being shown in their adaptation to the particular requirements of different types of vessels engaged in different fisheries for different countries. Some of these are discussed in turn in relation to the vessel and fishery as a whole. Some consideration is also given to possible future developments. The advantages of freezing whole fish at sea, as opposed to fillets, are also discussed in relation to space and handling arrangements on board the vessels, labour requirements, and above all, retention of quality standards as near as possible to the fresh state, within the limits of practical and economic possibility in relation to the scientists' laboratory ideals. Some remarks are also included on freezer capacity in relation to catching rate.

Evaluation des techniques et du materiel modernes pour la congélation du poisson entier en mer

L'idée de congeler le poisson entier en mer, par opposition à la mise en glace traditionnelle, a été inspirée à l'origine par le souci de réduire au minimum les modifications à apporter aux chalutiers classiques. Ces derniers temps, on cherche surtout à réduire les frais en capital, les dépenses de fonctionnement et les problèmes de main d'oeuvre dans les navires congélateurs: pour cela, on concentre autant que possible les opérations de préparation et de transformation à terre, ce qui permet d'en réduire fortement le coût et de travailler à grande échelle. Malheureusement, dans certains pays, l'intégration verticale de la pêche proprement dite au traitement et à la distribution à terre, n'est pas encore suffisamment développée, de sorte que les méthodes de congélation du poisson entier en mer, si elles assurent une rentabilité maximum pour l'armateur, ne correspondent pas toujours parfaitement aux besoins du marché.

Le choix de la meilleure méthode de congélation du poisson entier en mer dépend de nombreux facteurs: fonds de pêche, climat, variétés de poissons, types de navires, équipement portuaire et installations pour le traitement du poisson à terre, méthodes de distribution, préférences des consommateurs, etc. Il existe trois méthodes fondamentales de congélation: refroidissement par ventilation à grande vitesse, par contact et par immersion. Chacun e est susceptible de nombreuses variantes, et toutes sont constamment perfectionnées en fonction des types de navires, de la pêche ou du pays. Quelques exemples sont rapportés à des navires déterminés et à la pêche en général. L'auteur étudie également les perspectives d'avenir et examine les avantages que présente la congélation en mer des poissons entiers, plutôt que des filets, de divers points de vue: espace, manutention à bord, main-d'oeuvre et surtout qualité; sur ce dernier point, il s'agit d'assurer une qualité aussi proche que possible de celle du "frais", dans la mesure où ce qui est théoriquement possible, en laboratoire, peut être réalisé dans des conditions rentables. Il est également fait état de la capacité des congélateurs par rapport à la cadence des prises.

Evaluación de las técnicas y equipos modernos para la congelación del pescado entero a bordo

La finalidad original de la congelación del pescado entero a bordo era reducir al mínimo los cambios que había que introducir en los arrastreros de tipo convencional que transportan el pescado conservado en hielo; después tenía principalmente como objeto limitar los gastos de capital y de explotación, así como los problemas relativos a las tripulaciones de los barcos congeladores, dejando que la mayor parte posible de las operaciones necesarias de preparación y de elaboración se hagan en tierra, en donde pueden efectuarse mucho más económicamente y a gran escala. Por desgracia, la integración vertical de las capturas y de los aspectos industriales de elaboración y distribución en tierra no ha avanzado lo suficiente en algunos países y, por tanto, la congelación del pescado entero a bordo no siempre se lleva a cabo en la forma más conveniente para el mercado, aunque sí tal vez desde el punto de vista puramente económico de los propietarios.

La eficacia de los métodos de congelación del pescado entero a bordo depende de numerosos factores, como los caladeros, el clima, la variedad del pescado, el tipo del barco, las instalaciones de transformación costeras y portuarias, los métodos de distribución, las preferencias del consumidor, etc. Los métodos básicos de congelación son tres: por corriente de aire, por contacto y por inmersión aunque cada uno de ellos ofrece numerosas variaciones, esforzándose constantemente por adaptarlos a las particulares necesidades de los diferentes tipos de barcos que trabajan en las pesquerías de los diversos países. Algunas de ellas se discuten en relación con el conjunto barco-pesquería, teniendo también en cuenta los posibles adelantos que puedan conseguirse. Se discuten también las ventajas que presenta la congelación del pescado entero a bordo en vez de partirlo en filetes, en relación con el espacio disponible en las instalaciones de los barcos, la mano de obra necesaria y, sobre todo, la conservación, en la medida de lo posible, de todas aquellas calidades propias del pescado fresco, dentro de los límites de las posibilidades prácticas y económicas. Se hacen también algunas observaciones sobre la capacidad del congelador en relación con la capacidad de captura.

WHEN one remembers that, apart from a few isolated experiments, modern fishing methods and freezing and processing at sea are less than 20 years old, it is remarkable how far we have progressed in the application to the fishing industry of modern engineering and other techniques. Up to the early 1950s all the medium and larger vessels used steam and most were coal-burning, the only mechanical aid on the fishing side was the winch, fish was brought on board, gutted, washed and stowed in ice, all by hand and mostly on the open wind- and spray-swept deck, often with ice covering every surface during the long Arctic night.

The fish industry on shore was geared to the handling of wet fish from, and often on the auction market, and

almost entirely by hand, whether filleting or smoking. Possibly the only exception was the canning industry, but even here a large amount of manual labour was, and continues to be required. Many premises were indescribably unhygienic, and distribution was mostly in insanitary wooden boxes, usually with inadequate ice. It was often said that more damage was done to the fish during and after landing than in the usually much longer period on board the fishing vessel.

The modern development of quick freezing started on shore immediately after the Second World War, though often only of fish which could not be sold fresh, the results of which took several years to overcome; freezing and refrigeration can never improve an initially poor product. In 1948, Chr. Salvesen and Co. Ltd. adapted their long whaling experience to the development of stern trawling from large vessels, first in the converted corvette *Fairfree* and then in the *Fairtry*, built at Aberdeen in 1953, and the first full-scale factory stern trawler in the world. In both these vessels freezing was in trays in Bird's Eye horizontal plate freezers and in "Fairfreezers", combined contact and blast freezers.

Rudolf Baader spent nearly 40 years in developing his range of fish processing machines and a selection of these were fitted in the *Fairtry*. Only a few had at that time been installed anywhere, and it is probably true that in the ensuing years after 1953 more were fitted in the many U.S.S.R. factory trawlers of the *Pushkin* and succeeding classes than on shore, where traditional methods are still used extensively, although nowadays in competition in the more advanced countries with the large-scale modern fish factories, relying more and more on sea-frozen fish.

The development of processing machinery and weighing machines has not yet proceeded far enough to enable consumer packs to be produced economically at sea. It is understood, however, that this development is now well advanced, so that soon only economic factors will decide whether or not to produce consumer packs at sea.

Full-scale factory trawlers have been adopted by the U.S.S.R., Poland, East Germany, the Federal Republic of Germany and Japan, not to mention the very large factory vessels and motherships of many different types mostly operating from the U.S.S.R and Japan. Over 200 vessels now at sea are equipped with filleting lines; the latest filleting machines can be fitted with a device to remove the pin bones, which have, until now, been one of the obstacles to the production of consumer packs at sea (Diestel, 1967). The Federal Republic of Germany is the only west European country which has finally settled on freezing only fillets at sea, after evolving from part-freezers, some for whole fish and some for fillets. While this is the system which best suits the market, with present methods and crews the return to the owners is understood to be very poor (Heinsohn, 1967).

The concept of freezing whole fish at sea was based originally on reducing to a minimum the changes required in conventional trawlers compared with traditional icing methods. Latterly it has been concentrated on limiting the capital and running costs and crew problems associated with freezer vessels by leaving as much as possible of the preparation and processing operations involved to be done ashore, where they can be conducted much more economically, on a large scale, with cheaper and more suitable labour, including women, and under better discipline and control. Another factor in some fisheries is that the processing machinery does not yet exist to suit the varieties of fish to be caught (Diestel, 1967).

Whether to freeze fillets or whole fish at sea must of course depend on the demands of the market to be served. Unfortunately vertical integration and/or development of the shore processing and distribution sides have not proceeded far enough in some countries, so that whole fish freezing at sea is not always done in the way best suited to the market although it may be the most economical purely from the owners' point of view; the converse is also true where poor marketing methods have been adopted.

The actual freezing process, whether of whole fish or fillets, and whether ashore or on board ship, is only a small though important part of the whole procedure from the moment of catching to that of consumption as food. So far as the vessel itself is concerned, the treatment of the fish after catching and prior to and after freezing, as well as the time involved at each stage, are equally important. The fishing grounds and climate, fish variety, type of vessel, port and shore facilities, distribution methods, consumer preferences, etc., all affect what needs to be done on board to ensure that the frozen fish is landed in the condition and form best suited to the market (Ranken, 1967a).

The three basic methods of freezing remain air-blast, contact and immersion. There are numerous variations of each of these and increasing ingenuity is being shown in their adaptation to the particular requirements of different types of vessels engaged in different fisheries for different countries. Some of these are discussed in this paper in relation to the type of vessel and fishery as a whole. Consideration is also given to the all-important preparation and handling before and after freezing. Many of the engineering and technical details are covered in the literature and for the most part will not be discussed here (Anon, 1965; Eddie, 1961, 1964; Gianesi, 1963; Merritt and Templeton, 1963; Munton and Stott, 1967; OECD, 1965; Osti, 1963; Ranken, 1961, 1963, 1965a, 1965b; Slavin, 1964; Slavin and Carlson, 1963; Slavin and MacCallum, 1963; White Fish Authority, 1956).

Catching methods in relation to processing and freezing rate and variety

By far the larger proportion of fish frozen at sea is caught by bottom trawlers, and very high catching rates have sometimes been quoted of 60 and 70-t/day or more. However, averages of usable fish are well below 20-t/day in most northern fisheries and 35 to 40-t/day seem to be reasonable maxima. These figures are for vessels up to about 73 m (240 ft) overall. Larger vessels may catch somewhat more since the maximum size and weight of gear which can be used is related to vessel size. Conversely middle water vessels will catch less. It has been stated by one experienced owner that a typical distant water vessel needs to average a catch of 12-t/day of whole fish to break even (Parkes, 1965). In the South African hake fisheries catching rates at present are substantially higher than in the northern hemisphere, but are declining in the same way, as exploitation increases. Catching rates in warm waters are normally much lower. Where

red fish is being saved as well as white, the above figures need to be increased substantially in some areas. In relation to these catching rates freezing plant with a capacity of 25 to 30-t/day actual frozen weight will deal with all except the occasional exceptional day, when some buffer storage will be required (fig. 1).

Purse-seining for tuna is now universal in the United States tuna industry and catching rates exceeding 75-t/day must be foreseen when designing the freezing plant, although it will only be working very intermittently at full output. In the past two or three years purse-seining has been used most successfully for white fish off Iceland, but so far as is known no freezer vessel has yet used this method.

Long-lining, as practised by the Japanese for tuna, seems to average about 10 to 12-t/day catching rate when a school is found and this is the size of freezing plant normally fitted.

For shrimp trawlers and lobster vessels a catching rate of 2 to 3-t/day is very good and much less is normal. Freezing rates of 1 to 2-t/day are more than sufficient for the parts that are saved.

Factory vessels must be planned in relation to the total combined average and maximum catch to be transferred from all their attendant catchers (Ranken, 1964).

A few years ago the catching rates given above would have been higher in most cases, but increasing competition has resulted in steadily declining catches, and this trend seems bound to continue unless international co-operation can be developed to the point where no fishery is exploited beyond its maximum sustainable yield. It is for FAO to co-ordinate efforts to reach this desirable goal and also to publish reliable statistics on which future vessels can be planned. At present everyone goes for the maximum catch irrespective of its effect on the fishery, and man is increasingly the greatest predator of all.

PREPARATION SPACE

If any preparation work is required before freezing, adequate space is essential for good results and this should be under cover and protected from the elements. Most of what follows applies primarily to trawlers, but the principles are equally important in other vessels.

Far too many vessels have been seen where the holding, sorting and preparation space is totally inadequate and unrelated both to the likely catching rates and to available freezing capacity. In the latter connection it must be stated that freezing capacity is often excessive in relation to realistic catching rates, and the space occupied, especially in the case of blast freezers, is also excessive in relation to the space left free for fish preparation.

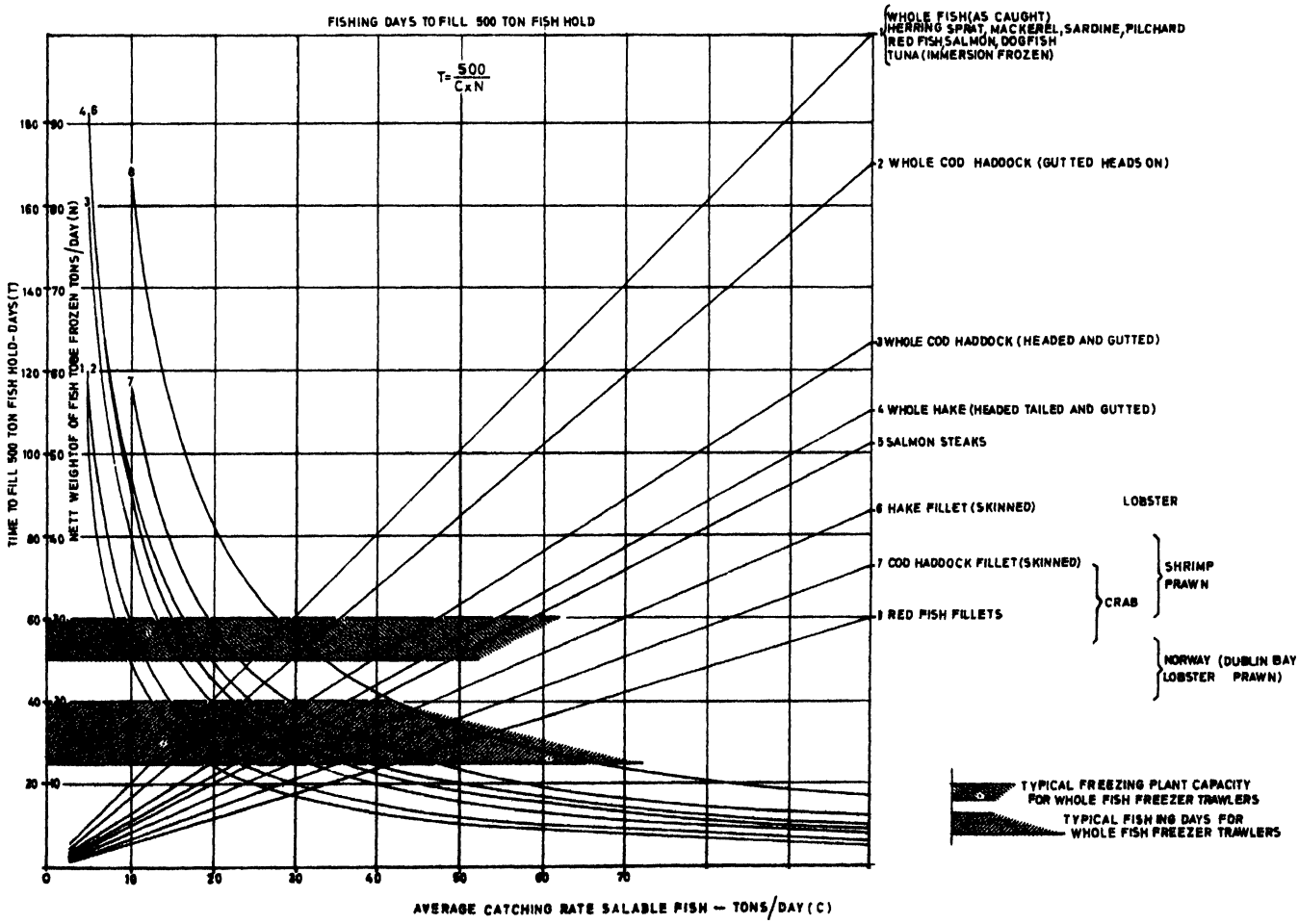


Fig 1. Fish freezing rate in relation to catching rate

In a normal stern trawler arrangement fish is discharged from the nets into the aftermost part of the 'tween deck down an inclined chute. It is therefore logical and usually convenient to arrange the processing lines, whether manual or mechanical, to flow forward and ultimately downwards into the frozen fish holds, preferably located in the midships to forward sections of the vessel. The lines should not cross each other, and there should be proper segregation between the fish to be saved, offals, discarded species, rubbish, etc. Good drainage of dirty washing water and fairing of obstructions is important to maintain hygienic conditions and avoid collections of rubbish, etc., which could provide a breeding ground for maggots and bacteria (fig 2).

Space below the chute must be adequate for holding the fish discharged from the nets and keeping it segregated from previous hauls, in case there has been any delay in sorting and processing. A German patent describes a revolving bin with radial divisions to be located below the chute and each segment to take one haul. It is doubted, however, whether in practice sufficient space could be made available for such an apparatus except in a large factory vessel dealing with transfers from attendant catchers.

When the vessel is to operate in warm or tropical waters, provision should be made for the immediate chilling of the catch with ice, chilled water sprays, or in chilled water tanks. The latter method is used in the East German *Tropik* and *Atlantik* (figs 3 and 4) class vessels. Sorting of the fish is undertaken after chilling (fig 5).

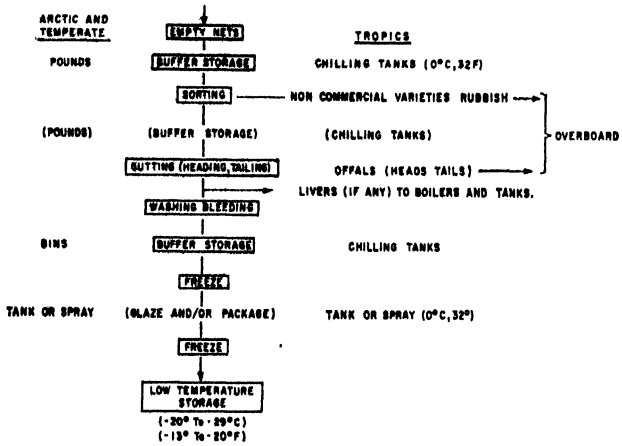


Fig 2. Preparation procedure for whole fish for freezing

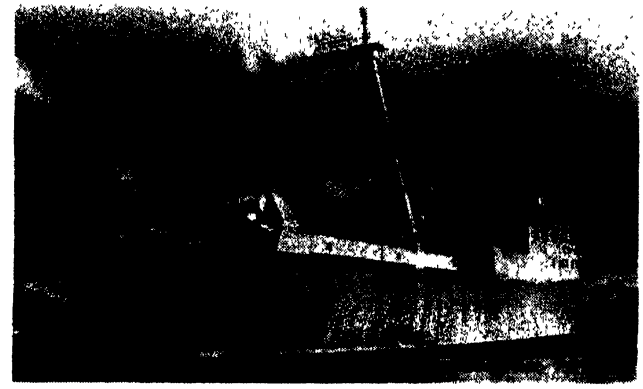


Fig 3. Freezer stern trawler Atlantik, *first of a series for tropical waters built in East Germany*

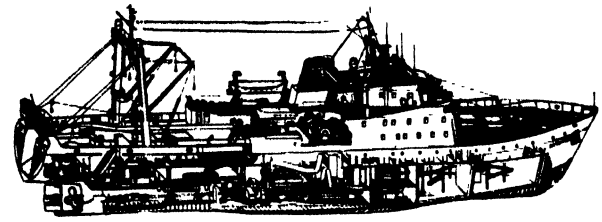


Fig 4. Cut-away view of freezer stern trawler Atlantik

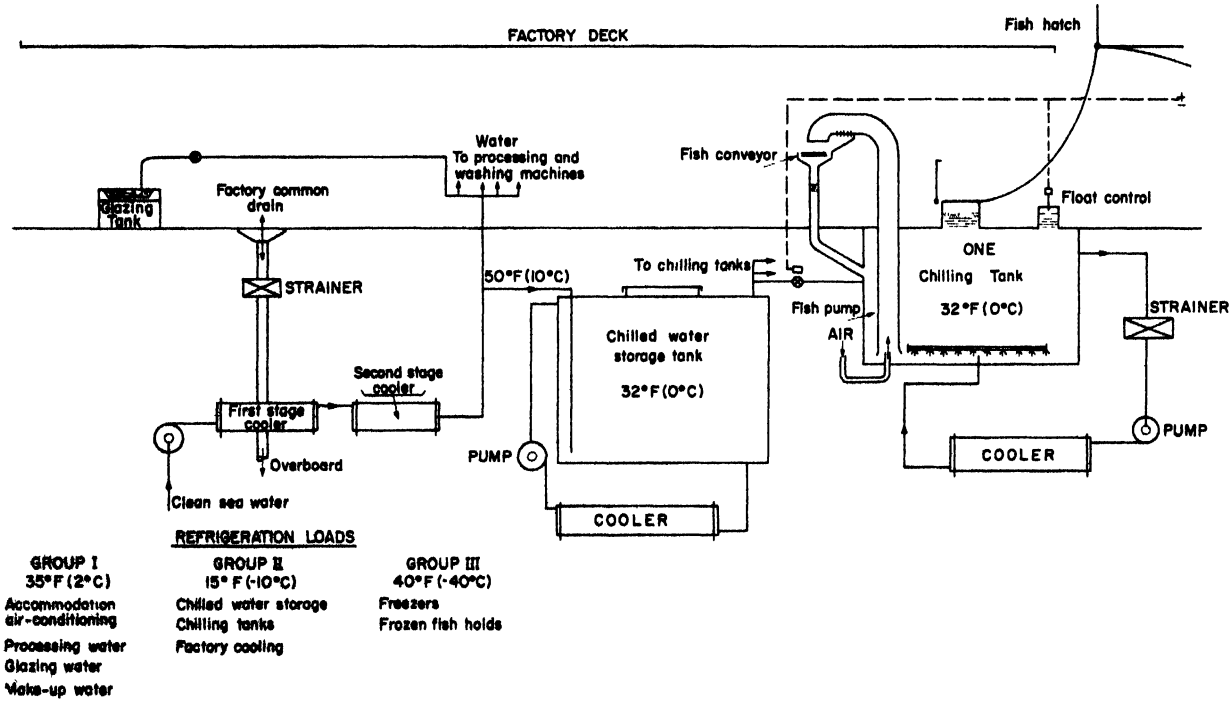


Fig 5. Diagram illustrating chilling requirements in hot climates

The purpose of chilling in the tropics is to retard the onset of *rigor mortis*, which can otherwise occur in as little as 40 min at 30°C (86°F). Fish should not, however, be held too long in chilled sea water as some varieties are spoiled and others become salty. Chilling can retard *rigor* long enough to enable the fish to be prepared, bled and washed, and passed into the freezers before it commences. If this is not done, buffer storage may be needed to allow time for the resolution of *rigor* before freezing, since freezing *in-rigor* can cause damage to the fish, as well as poor blocks. Some fish if frozen *post rigor* are quite unsalable after thawing.

In lobster vessels space is needed for purging the live lobsters for a few hours before preparation and freezing.

Most vessels rely solely on manual labour for gutting, heading and washing prior to freezing, and the freezers themselves are loaded and unloaded by hand. More recently, however, heading and gutting machines have been introduced in some vessels, and various types of rotary and tank washing machines have been used. It is important to provide sufficient time for bleeding before freezing, and washing tanks are often better in this respect than, or in addition to, the rotary machines. It is important that only clean sea water is used for washing, as fish flesh readily absorbs off odours or tastes.

The decision whether to save the offal and rubbish for fish meal must depend on the varieties being saved, the proportion of material available, and the likely state of the fish meal market. Many vessels save cod livers, but few whole fish freezing vessels seem to have fish meal plants installed. Adequate provision must therefore be made for discharging rubbish overboard.

After preparation and bleeding the fish must be held ready for freezing, since the freezers operate on a regular cycle, while fishing and processing are irregular, depending on catching conditions. This is the obvious time for any buffer storage and separation of species and sizes which may be necessary, but it is difficult to design buffer stores which ensure that first fish in is always first out.

Some measure of mechanization of handling is possible, using conveyors, chutes, etc. Several ingenious systems have been devised for loading and unloading the freezers mechanically, using electric, electro-pneumatic, mechanical or hydraulic systems as well as gravity. Whether these systems are necessary or desirable depends on the freezing method in use and the throughput.

Working conditions in the preparation spaces of some vessels have been improved by cooling of the air, though seldom by full-scale air-conditioning, and by underfloor heating, where the space is directly above a low temperature hold. Stabilizer tanks have also been fitted in some recent vessels to dampen the rolling.

Handling of frozen fish after freezing

Depending on the variety, the fishery and the freezing method, as well as on the preferences of the owner, frozen fish may be glazed and/or packaged after removal from the freezers, or it may be stowed bare. Glazing may be done by water sprays on a conveyor after removal from any containing trays, or by dipping in a water tank, usually by hand.

In some vessels the blocks are packed in cartons or boxes after freezing, two or three to each; sometimes the fish is packed in boxes before freezing. In others, vacuum packing is used in polythene bags; if packaged before freezing in an air-blast freezer the time is increased by about 10 to 20 min. The films used do not stick to the cold metal parts of the freezer. In general, glazing is not required if proper packaging is in use to avoid desiccation during storage.

In the recently completed *Natalia Korshova* class fish canning factory vessels built in France for the U.S.S.R., frozen fish is only produced at times of heavy catches, this fish being thawed later on board in a dielectric thawer and used for canning when catches are light.

FROZEN FISH HOLDS

Storage temperature

Since by far the greatest time between catching and consumption is spent in storage—on board ship, in shore cold stores, in transit, in shops and in domestic refrigerators—it is most important to take proper precautions to maintain correct and even storage conditions of temperature and humidity throughout the cold chain. It is also of the greatest importance during distribution to ensure that the principle of "first in, first out" is practised as far as possible in all cold stores and cabinets whether large or small, since deterioration increases with time, however good and even the storage conditions, and is aggravated by temperature fluctuations (Peters, 1964; Lorentzen, 1963).

In ships' holds a temperature of −29°C (−20°F) is now standard in the United Kingdom and some other countries, while −25°C (−13°F) is practically universal in the Mediterranean and many other countries; while Japanese vessels used to be content with −20°C (−4°F), newer vessels use −25°C (−13°F). In general, the tendency is towards lower temperatures, though −29°C (−20°F) seems to be low enough for all practical purposes. An exception is brine frozen tuna for the United States canning factories which is normally stored at −18°C (0°F).

Layout

The layout of the frozen fish holds on board fishing or factory vessels should be such as to achieve the best possible stowage rates for the whole of the catch, while maintaining the optimum storage conditions. Ideally all holds should be in the square section of the vessel, neither too far forward nor aft. It is also much better to avoid using 'tween deck spaces, since stowage rates are always poor in a low headroom, and heat losses are inevitably greater in relation to the gross volume occupied; where the intermediate deck separates the 'tween deck from the hold, both at low temperature, heat losses are increased unless excessive insulation is used, and special steels are usually required to withstand the low temperature.

The best stowage rates are achieved where all pillars and pound boards are eliminated and the cooling elements, whether grids or air coolers and ducts, provide an envelope between the insulated surfaces and the cargo. It is important that there is free air circulation over all insulated surfaces, including the floor, and round but not through the cargo, except perhaps in fish-carrying

vessels, where provision must be made for receiving the cargo above the specified carrying temperature. Usually, however, it is sufficient to allow the fish to reach equilibrium by radiation and conduction, the mean temperature having first been reduced to just below carrying temperature in the freezers.

Inert gas is mentioned in the literature as an aid to storage, but it is doubted whether it is worthwhile in comparison with the maintenance of even low temperatures during normal storage periods.

Palletization is normal practice in land cold stores and it is suggested that it could usefully be considered for ships' holds as a means of reducing the time and labour required for discharging the cargo and perhaps also for stowing it. Hatch sizes also need to be selected which suit the pallets, even if these are only introduced during cargo discharge in port. The importance of improving block handling will be clear when it is remembered that only about 15-t/h per hoist of loose whole frozen fish can be discharged in most ports, whereas with say 1-t pallet loads of blocks this could be increased to at least 150-t/h.

Paternoster lifts have been used for discharging blocks individually, but the space occupied, and the slow rate of operation, as well as the difficulties with broken blocks, make it a poor system in most vessels; it should be better for cartons or boxes, depending on their size. Belt or roller conveyors may, however, be useful for stowing and discharging blocks, cartons or boxes.

In British practice, blocks of whole fish are stowed bare, but no trouble has been experienced either with sticking of the blocks or with sliding.

Block size

It is most important to choose a block size which suits the market, the freezer and the hold layout. For whole fish blocks the market will presumably accept the largest size which is convenient for handling on board. For economy in the size of the freezers, the outside dimensions of the blocks should be as large as possible (usually about length = 2 × width) and the thickness the greatest which can be accepted in relation to a reasonable freezing time. A thickness of 102 mm (4 in) has become a standard for vertical plate freezer blocks and somewhat less for blast freezers. Probably the maximum which could be used might reach 152 mm (6 in) in a contact freezer.

Very poor stowage rates are achieved with individually frozen fish both when stowed indiscriminately (118 ft^3/t; 0.3 t/m^3) and even when laboriously arranged by hand (70 to 80 ft^3/t; 0.45 to 0.5 t/m^3). This method of freezing is not therefore common except for tuna.

Block sizes for gutted and headed whole white fish in vertical plate freezers average up to 53 to 55 kg (116 to 120 lb) and when stowed bare can reach a stowage rate of 55 to 60 ft^3/t (0.6 to 0.65 t/m^3). This compares well with regular fillet blocks at 47 to 50 ft^3/t (0.7 to 0.75 t/m^3). Carton storage should not greatly affect matters, though naturally the smaller the block size chosen for whole fish, and especially if the heads are left on, the worse will be the stowage rate.

FREEZING METHODS

Whatever we wish to freeze, there are only three basic methods available, freezing in air or inert gas, freezing by direct contact, and immersion freezing, or in some cases a combination of these. However, in recent years there have been many ingenious applications of these methods to particular produce and some of these have been especially for various forms and varieties of fish.

In general if best possible quality is to be maintained, fish should be quick frozen and this is usually defined as cooling the whole of the fish through the range 0° to −5°C (32° to 23°F) in under 2 h and keeping it in the freezer until the temperature at the middle of the thickest part reaches −20.6°C (−5°F) or lower (White Fish Authority, 1956). This is obviously easier to achieve the thinner the fish, the better the heat transfer, and the lower the temperature of the cooling medium. There are, however, practical limits to all of these which will be discussed below (table 1). The Soviet definition of quick freezing stipulates that the fish must freeze at a rate of not less than 3.3 cm/h (1.3 in/h) through the range 0° to −5°C (32° to 23°F) (Zaitsev, 1962).

TABLE 1. FACTORS AFFECTING FREEZING TIME

Characteristics of product	*Characteristics of freezing method*
Variety	Temperature at entry to freezer*
	Thermal arrest period (TAP)
Thickness	Temperature on leaving freezer (mean)
	Hold storage temperature*
Shape—whole, individual	Cooling medium (freezing method)*
whole, blocks*	Temperature of cooling medium (mean)
fillets, blocks*	Temperature rise (circulation rate)
fillets, consumer packs*	Static head effects—direct expansion
	pump circulation
Density (specific volume)	Humidity of cooling medium
Surface area	Cooler surface area
Specific heat above freezing }	Temperature difference (mean)
Average freezing point } Apparent specific	Heat transfer coefficient—Product to cooling medium
Latent heat of fusion } heat	Velocity of cooling medium
Specific heat below freezing }	Distribution of cooling medium
Thermal conductivity (thermal diffusivity)	Method of heat transfer
	Effect of packaging material and/or trays*
	Refrigeration capacity of cooler relative to total freezing time *or* TAP
Remainder fixed by product	Remainder usually at discretion of designer

* Usually specified.

The maximum thickness for quick freezing is about 15 cm (6 in) with 10 cm (4 in) as more usual in practice. The latter thickness will accommodate most commercial varieties and sizes of whole white fish (cod, haddock, hake, etc.) and red fish, herring, sardines, mullet, shellfish, etc. Of those commercially exploited, only the large pelagic varieties like blue- and yellow-fin tuna, swordfish, marlin, etc., which commonly reach 70 to 90 kg (150 to 200 lb) or more, and 30 to 40 cm (12 to 16 in) in thickness are outside the limit for quick freezing.

For a given temperature difference heat transfer is worst with air or an inert gas due to their low specific heats, and would presumably be best of all if a refrigerant of high latent heat could be evaporated directly from the fish surface. In practice the best heat transfer is probably obtained in a contact freezer, though for whole fish, immersion freezing should be better provided the liquid used is suitable, permits the use of a sufficiently low temperature, and can be circulated over all the fish surfaces at a sufficiently high velocity to maintain a high surface heat transfer coefficient. This is not achieved in any existing immersion system used on board ship.

The lower limit of temperature of a freezing medium with a high surface coefficient of heat transfer is in the region of −50°C (−58°F) for immersion freezing, if mechanical damage is to be avoided due to excessive temperature gradients through the fish (Merritt, 1966; Lorentzen, 1964). With other freezing methods which are less efficient, much lower temperatures can be used safely, but the limit is again dependent on not generating excessive internal stresses in the fish flesh. For most freezing methods we also have a practical lower temperature limit set by economic considerations of refrigerating machinery size and operating cost in relation to evaporation temperature. Normal refrigerating machinery for freezing plant on board ships is designed for a minimum evaporation temperature of −35° to −40°C (−31° to −40°F) under maximum operating conditions. The temperature will of course drop much lower when freezing rates are below the maximum and sea water temperatures are reduced.

To halve the freezing time, e.g. by dropping the freezing temperature from −25° to −50°C (−13° to −58°F), the compressor size (swept volume) must be increased by about four times and the absorbed hp is more than doubled.

With an infinite surface heat transfer rate, the limit on freezing rate is set by the coefficient of thermal conductivity through the fish flesh, and this in turn is lowest through unfrozen flesh and increases rapidly as freezing proceeds and then more gradually as the temperature drops. The thermal conductivity of fish immediately below its initial freezing point (−2° to −8°C; 28.4° to 17.6°F) is almost three times its value above 0°C (32°F), and increases as the temperature drops further. Incidentally it is for this reason that freezing can be done more quickly than thawing, except by the dielectric method, which does not rely on conduction through the external surfaces of the fish flesh. Whatever freezing method is used, the freezing time varies approximately as the square of the thickness.

Evaporation, cooling medium, holding and fish temperatures. Compressor ratings

This seems an appropriate point at which to draw attention to the confusion which so often arises in shipyards' or owners' specifications and in descriptions of installations, between refrigerant evaporation temperature, freezing medium temperature (air or liquid), holding temperature and fish temperature. It is reasonable to specify the fish holding temperature required, e.g. −25°C (−13°F), and the minimum freezing rate required for a given maximum thickness, e.g. 3 h from 0° to −20°C (32° to −4°F) at the centre of the fish. If, however, the freezing medium temperature is stated, it is necessary also to state the temperature range under maximum freezing conditions, e.g. 6°C (11°F) for air or 1.7°C (3°F) for liquid. In the case of direct expansion in a contact freezer, either a minimum or average evaporation temperature can be specified, depending on the method of control, e.g. −40°C (−40°F) in a vertical plate freezer with pump circulation, or an average of −20°C (−4°F) in a horizontal plate freezer with thermostatic regulators. At the end of a normal freezing cycle the fish temperature will range from close to that of the freezing medium on the outside—perhaps −35°C (−31°F) in a freezing tunnel —to, say, −20°C (−4°F) at the centre; the aim should always be to reach a mean fish temperature a few degrees below the intended holding temperature, e.g. −27°C (−17°F) for subsequent storage at −25°C (−13°F).

It is not sufficient to specify either the evaporation temperature or the lowest cooling medium temperature or both. Many plants have been seen where the compressor capacity at the specified evaporation temperature is ample for the maximum freezing duty, but the air circulation rate and cooling surface are so low in the associated freezing tunnels that quick freezing is impossible at anywhere near the full output and there are excessive temperature variations throughout the tunnels. The owner may obtain a cheap plant but it will not do what he specified and the excessive temperature differences are likely to cause freezer burn and excessive desiccation (fig 6).

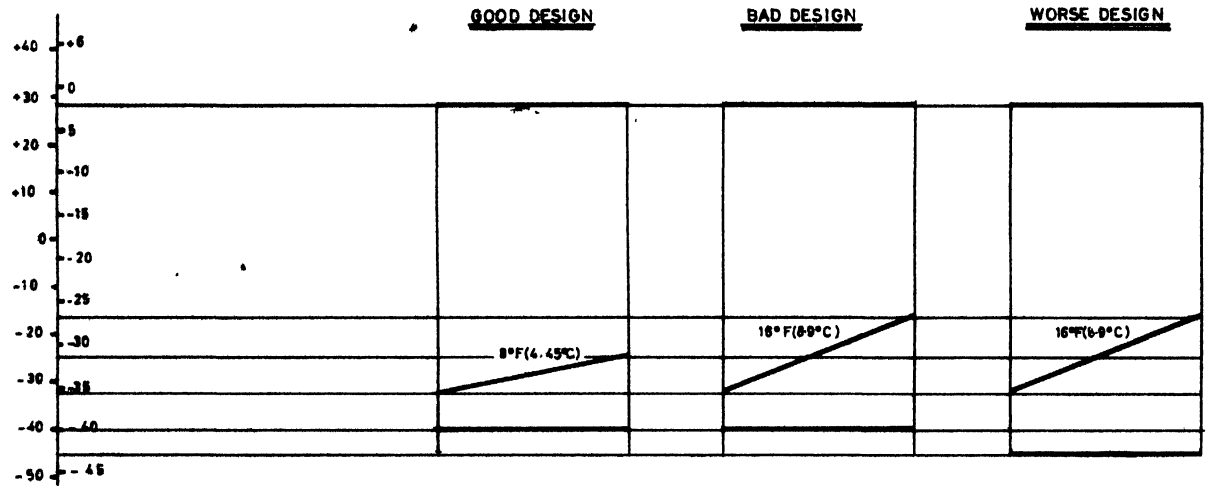
Zaitsev (1962) advocates designing the freezing plant capacity in relation to the thermal arrest period (TAP) of the fish and not using an average for the complete freezing cycle. Apart from the lack of accurate information on the length of the TAP under different conditions, the increase in size of plant is such that it is doubtful whether most owners would be prepared to face the greatly increased cost of plant unless the scientists could show a sufficiently spectacular improvement in quality to justify it.

It should also be stated that rating compressors for low temperature freezing applications over an evaporation/condensation temperature range of −15° to 30°C (5° to 86°F) is quite unrealistic, since the compressors are almost certainly compound and could not conceivably work under these conditions in any practical installation. They should be rated under possible operating conditions, e.g. −40° to 40°C (−40° to 104°F), and these temperatures should be stated.

Freezing in air

Frozen fish hold. The most primitive method of freezing is in a cold chamber held at the required low temperature.

FREEZING CAPACITY : 15 TONS/DAY HAKE IN 3 CYCLES OF 8 HRS. FREEZING TIME 7 HRS. FROM 72°F (22°C) TO -13°F (-25°C) FISH COOLING LOAD. 300,000 BTU/HR (75,000 KCAL/HR.) COOLING LOAD ON TOTAL FREEZING TIME, NO THERMAL ARREST PERIOD. COOLER ¾ IN. (19 M.M.) 0-D. PLATE FIN 2 PER IN. (79 PER M.) U=8·2 BTU/FT²/HR/°F. (25·4 KCAL/M²/HR/°C.).



AIR VOLUME	CFM	M³/HR	28,300	48,100	14,150	24,050	14150	24 050
FAN HORSE POWER	HP.		16·8		6·25		6 25	
COOLER LOAD	BTU/HR	KCAL/HR.	357,400	90,000	321,300	81,000	321,300	81,000
L.M.T.D. COOLER/EV. GAUGE	°F	°C	11·5	6·4	14·5	8·05	19·45	10·8
COOLER SURFACE	FT²	M²	6000	558	4,260	396	3180	296
COMPRESSOR SW. VOL.	FT³/MIN	M³/MIN	358	10·13	322	912	368	10 13
AIR VELOCITY e.g.	FT/MIN	M/SEC	900	4·58	450	2 28	450	2·28
MEAN AIR HUMIDITY (APPROX.)	%		54		43		31·5	
MINIMUM T.D. F.P. FISH/AIR	°F	°C	52	28·9	44	24 4	44	24·4
ACTUAL MEAN FINAL TEMP. e.g	°F	°C	-15	-26 1	-5	-20 6	-5	-20·6
TYPICAL SPECIFICATION:								
EVAPORATION	°F	°C	-40	-40	-40	-40	-44·5	-42
CONDESATION	°F	°C	100	32	100	32	100	32
AIR TEMPERATURE	°F	°C	-32	-35 6	-32	-35·6	-32	-35·6

Fig 6. Example of good and bad designs of air blast freezing tunnels, air coolers, etc.

This method is used in the *Gillian Gaggins* where lobster tails are packed in boxes and placed directly in the fish hold. It was also used in earlier vessels operating off Tristan da Cunha and has presumably been found to produce adequate results without excessive desiccation or loss of quality due to the slow freezing and fluctuating temperatures. The method has also been found adequate in several freezer vessels catching small quantities of such large fish as halibut which will not go into their freezers. At the other end of the scale it is used successfully in small shrimp freezing vessels.

Shelf freezers. A refinement of the above method is to place the fish on shelves or in trays in intimate contact with cold pipe grids arranged below them. Cooling in this case is by contact partly with the cold pipes and partly with still cold air. Further improvement is possible by fitting small fans to circulate the air along the shelves and this method has been used for lobsters, e.g. in the *El Mafran*. A much more sophisticated version of this is the "Fairfreezer" as fitted in the *Fairfree* and in the *Fairtry*.

Freezing tunnels. By far the majority of freezer vessels use air-blast freezing tunnels in which low temperature air is circulated at a high velocity over the fish, either individually or in a variety of packages or trays. Individual tunnels range up to 50-t/day and may be of the batch or continuous types. Air circulation may be longitudinal or cross-flow, the latter being preferable and normally involving a lower temperature gradient. Normal air velocities are in the range 2.5 to 5 m/s (500 to 1,000 ft/min), though up to 10 m/s (2,000 ft/min) has been advocated in some cases for thin blocks. Beyond a certain point, depending on the product shape and form, there is little value in very high air velocities, which inevitably involve larger fans and therefore greater fan power. It is important to have adequate air circulation and a reasonable air range over the fish to reduce moisture pick up; 4.5° to 5.5°C (8° to 10°F) is a reasonable air range under maximum load conditions. In some designs of freezing tunnel the air quantity and hence fan size and horse power, are greatly reduced by splitting the air cooler and alternating sections of cooler with batches of fish to be frozen. This is more common in batch than in continuous tunnels.

The mean temperature differences between the air in the tunnel and the associated air cooler surface should be as small as practicable consistent with maintaining a reasonable size of air cooler. Typically a mean temperature difference of 6.5° to 8.5°C (12° to 15°F) is reasonable to avoid excessive desiccation. Air velocities through the air cooler are usually in the range 2.5 to 4 m/s (500 to 800 ft/min), the limit again being set by fan power in relation to air volume and frost formation.

Since noise is seldom a problem, air velocities in return air ducts are not critical and may be in the range 15 to 25 m/s (3,000 to 5,000 ft/min) consistent with avoiding excessive pressure drop.

To anyone who has had to design freezer tunnels in ships with very restricted space, especially in 'tween decks, the advantages of high air velocities will be obvious. One is usually in great difficulty in restricting the velocities to reasonable values, and great ingenuity is often needed to find the most suitable compromise between air volume, air velocities, temperature differences and fan power in relation to evaporation temperature and optimum freezing time relative to fish variety and product form.

It has already been stated that precooling of the fish immediately after catching is desirable in hot climates to retard *rigor*. It is also desirable in freezing tunnels to reduce desiccation as well as frosting of the cooler surfaces. The fish should preferably enter the tunnel below 10°C (50°F). With a conveyor tunnel it is comparatively simple to arrange a precooling section before the fish enters the main freezing area. With the more common batch freezers, however, this is more difficult and so far as is known has not been done. It would, however, be possible with some designs by arranging for the first part of the cooling to be done with higher evaporation and hence air temperatures.

Freezing is always quicker if the fish is unpackaged and this is normal for large fish like tuna or halibut which are usually suspended on hooks. Smaller fish are, however, packed in boxes, cartons or trays, which should preferably be metal and fitted with lids where blocks are to be produced.

Commercial blocks or packs of whole fish frozen at sea in blast freezers mostly vary between about 8 and 12 cm (3 and 5 in) in thickness and 15 to 22 kg (33 to 49 lb) in weight, though for at least one class of Soviet factory vessel specializing in small fish, the thickness is only 57 mm (2¼ in) and the block weight 10 kg (22 lb). With a mean air temperature of −33°C (−28°F) a temperature rise of 4.5°C (8°F) and an air velocity of 4.6 m/s (900 ft/min), fish blocks 8 cm (3⅛ in) thick can be cooled from 10°C (50°F) to −20°C (−4°F) in about 4 h 20 min; for blocks 12 cm (4¾ in) thick the time would be about 7 h 40 min. In the latter case quick freezing is not achieved, and the maximum thickness which could be quick frozen under these conditions is about 8.2 cm (3¼ in). With an air temperature of −40°C (−40°F) at 9 m/s (30 ft/s), an 8 cm (3⅛-in) block should freeze through the same range in 2½ h, but the use of such a low temperature with conventional refrigerating machinery would seldom be justified in commercial practice. However, the thinner the block thickness, the greater the advantage, since the effect of thermal conductivity on freezing time is reduced.

Common freezing cycles on board ship for batch freezers are either 10 h or 7 h depending on the preferred method of operation by the crew, rather than on the ideal from the purely refrigeration point of view. The remaining time is required for unloading, reloading and defrosting. It will be obvious that the longer freezing cycle becomes essential for the thickest block thicknesses; the maximum which can be frozen satisfactorily in 7 h is about 11 cm (4⅜ in) under the above conditions.

Batch freezers. In normal-sized trawlers, such as are used in Spain, Italy and various other countries, two air-blast freezers are commonly provided, one on either side of the vessel, at the forward end of the preparation space. With a typical maximum capacity of 30 t/day and on the more usual two-cycle system, each tunnel has a capacity of 7.5 t of fish and the time required for unloading and reloading, as well as the sheer weight of hot fish at up to 25°C (77°F) or more, means that the whole structure of the tunnel as well as the fish must be cooled from this temperature on each cycle. One tunnel will be filled with fish every 6 h, so that some fish will wait at least this time before freezing starts; it may well be much longer during heavy fishing. Not only can this result in marked deterioration, with probably the onset of *rigor* in some of the fish, but the sudden loads on the refrigeration plant at the start of each freezing cycle usually cause a corresponding rise in air and hence evaporation temperature over the first 30 to 45 min of the cycle. This in turn results in a sudden increase in electrical consumption by the compressors, which can place a severe strain or even an overload on the ship's normal generating capacity; this is quite apart from the effect of a rise in evaporation temperature on the conditions in the other tunnel already half-way through its freezing cycle, assuming, as is common, that the suction lines are common from both tunnel air coolers (Akerman, 1964) (fig 7).

One way in which this problem can be overcome is by dividing the freezing capacity between six or preferably eight freezing tunnels. It is also advantageous to use three cycles/day on each tunnel, provided that the fish or block thickness makes this possible. Thus for 30-t/day total capacity with eight tunnels on three cycles, each has to accommodate only 1¼-t, and one will be loaded every hour. Notice that the total capacity of the eight tunnels is only 10-t compared with 15-t on the two-tunnel two-cycle system. Some saving in space occupied by the tunnels may therefore be possible and much smaller batches of fish should need to be stored before loading into a freezer. Fluctuations in air and therefore evaporation temperature can be minimized, to such an extent as to have almost no effect on the overall compressor power consumption, and hence on the ship's electric generators. Another advantage of smaller batches is that fish handling is easier and time required is reduced.

Various means have been adopted for mechanization of fish handling into and out of batch freezers, with fore and aft and athwartships conveyors, hydraulically, pneumatically, mechanically or electrically operated. Recent examples of these systems are those in the *Toula* and *Marcelina de Ciriza*. The systems in the *Pushkin* and many later U.S.S.R. factory trawlers and in the Polish B18 class are also similar in conception, since in all of these vessels comparatively large batches of fish in trays have to be prepared in specially constructed racks and introduced periodically into the tunnels. These racks also provide storage for fish awaiting freezing, for frozen blocks awaiting glazing and storage after freezing, and for empty trays; they reduce to a minimum the amount of handling which is required (fig 4). Baader offers a design of trolley with a hydraulic system to maintain pressure on the trays during freezing; channels are provided between the trays for air circulation.

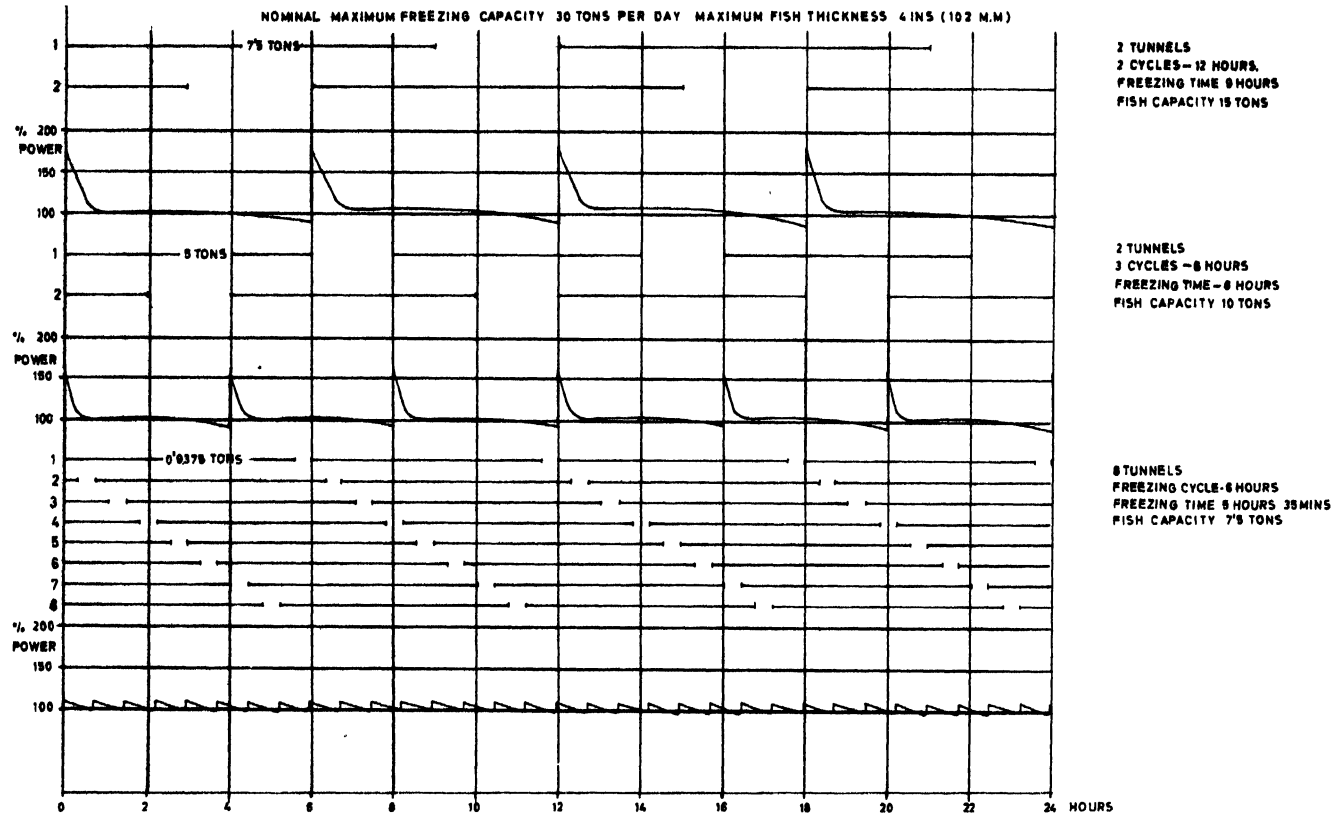


Fig 7. Freezing cycles per day of air blast freezers in relation to electric power fluctuations on ship's generators and nett fish capacity of freezers

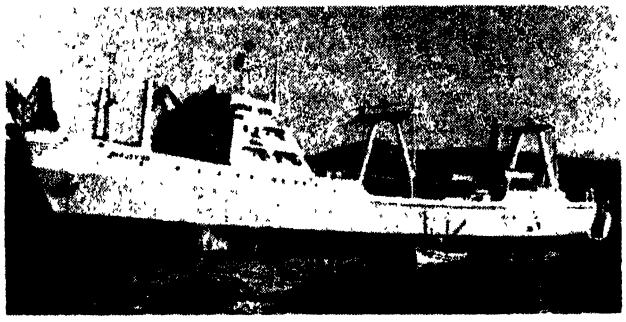


Fig 8(a). The colossal size of the Mar de Vigo *can be seen as a local coastal trawler passes alongside*

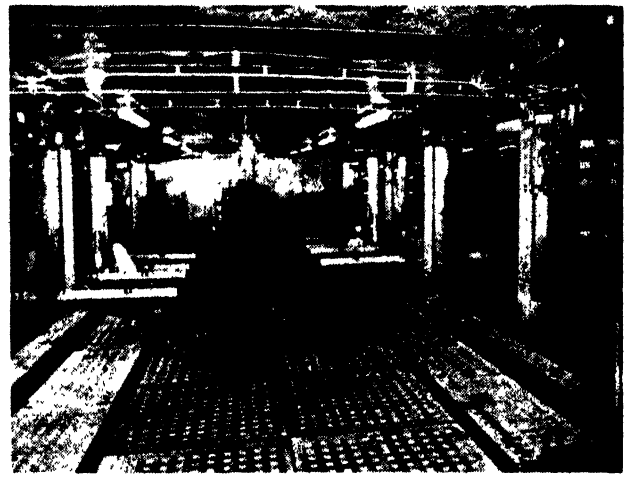


Fig 8(b). Freezer space in freezer stern trawler Mar de Vigo

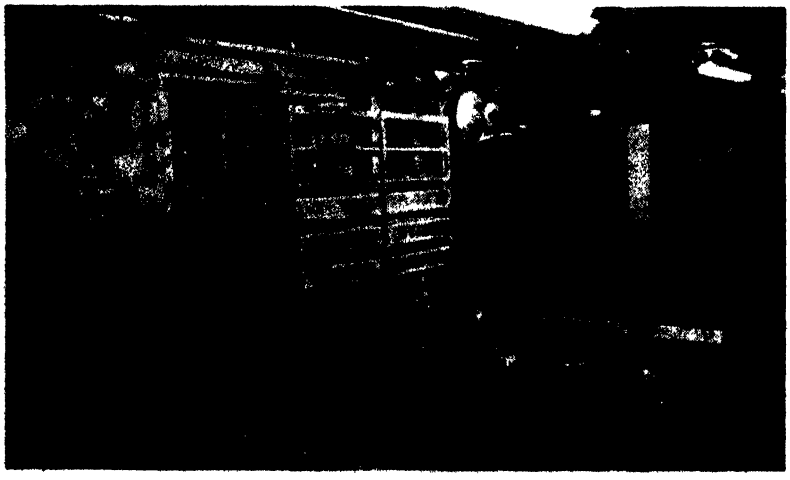


Fig 8(c). One tray rack partly entered into one of the eight freezer tunnels in the freezer stern trawler Mar de Vigo

Most freezer tunnels are designed for installation in a 'tween deck and therefore operate mainly in a horizontal plane. A novel design by Grasso fitted in the Greek vessel *Polikos* has a conveyor working in the vertical plane, the trays being filled three at a time at the top and the 16 kg (35 lb) blocks discharged at tank top level ready for glazing and stowage in the hold at the end of the freezing cycle. Filling takes about 20 min and provision is made to accommodate 8 or 16 cm (3 or 6 in) fish. Two tunnels are fitted with a total freezing capacity of 16-t/day (Anon., 1960).

Continuous tunnel freezers. Several designs of continuous freezers are in service at sea (fig 9b). That of Hoppe and Krooss was designed originally for whole fish, though it is also suitable for fillets. This was fitted first in certain German stern trawlers, such as the *Berlin* for individual whole cod. Later versions permit the use of trays to produce blocks of whole fish or fillets.

For the very large Soviet factory vessels, Burmeister and Wein and later N. V. Koninklijke Maatschappij "de Schelde" developed very sophisticated conveyor freezers, which are basically similar in conception (fig 10). In both, the freezer trays are permanently secured to chain conveyors, with detachable lids. Fish is supplied by hoppers and scales to the trays, where it is spread evenly and the lids are fitted manually. The trays then pass into the freezing tunnel. At the end of the freezing cycle they pass under an electric heater which releases the lids, and these are lifted automatically by cams and returned to the filling position. The trays are turned over and then continue under a second electric heater which releases the blocks, and these drop on to another conveyor which takes them to the glazing section, thence to the packing table and finally to the hold for stowage. A minimum number of men is required for operating these freezers, only two in the case of the "de Schelde" design, which has a capacity of 25-t per 22 h of 10 kg (22 lb) blocks.

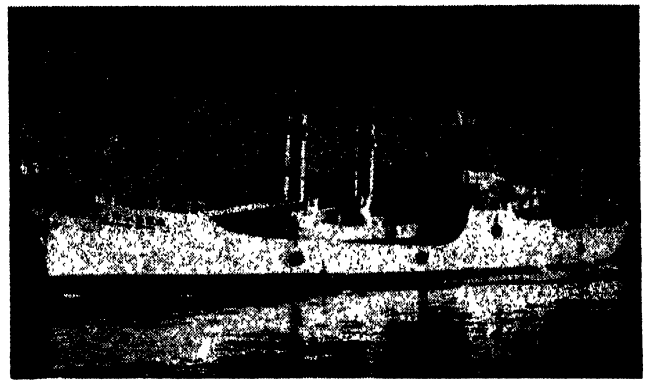


Fig 9(a). Japanese long-line freezer vessel Hoko Maru 31

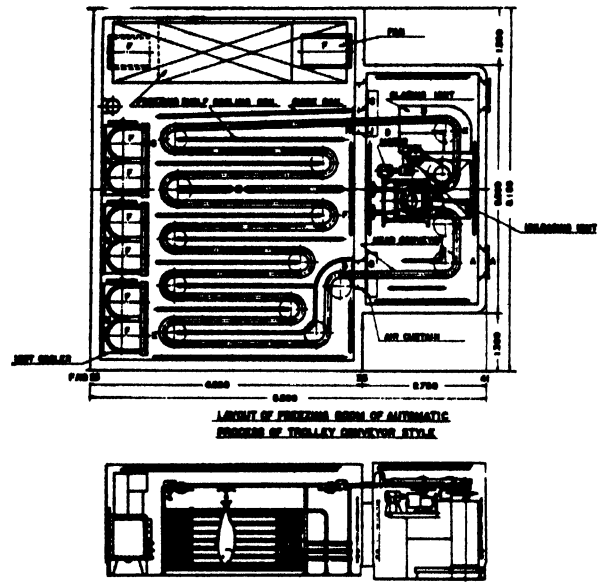


Fig 9(b). Continuous conveyor freezer as fitted in some recent Japanese long-line tuna freezer vessels

Fig 10. Tray-filling position in De Schelde freezing tunnel

The conveyor speed can be varied to obtain different freezing cycles to suit different products.

Many other conveyor freezers have been designed for use on land and some appear suitable for shipboard use, provided they are redesigned as necessary to take full account of ship movement, salt water, etc.

Another design of continuous freezer employs hydraulic or pneumatic pushers to move the trays through the tunnel on slightly inclined racks, so eliminating moving parts in the cold air stream. While there are certain complications in the loading and unloading equipment, the units are compact and suitable for shipboard use with a minimum of maintenance. A variation of this employs a spiral track surrounding the air cooler and fans.

The space occupied and the hp absorbed by a continuous tunnel freezer are considerably greater for a given output than by a batch freezer, and there is also a loss of flexibility. However, with good designs there is a spectacular saving in labour (Tchigeov *et al.*, 1967).

Fluidizing tunnel freezers. In the past few years the principle of fluidizing has been applied to many processes, and in the refrigeration industry was first used for chilling and/or freezing peas. In a fluidizing freezer the product to be frozen is individually suspended in the upward flowing cold air stream of the freezing tunnel, and hence the best possible heat transfer is achieved between the air and the product; figures of 73 to 98 kcal/m.^{2} °C.h (15 to 20 Btu/ft.^{2} °F.h) are quoted for peas, which compare favourably with any other common freezing method and is at least double what is achieved in a conventional blast freezer. In the fish industry fluidizing has been applied to shrimp freezing and is perfectly suitable for many small fish or fillets provided these are not too heavy in relation to the area presented to the air stream. Not only is every fish frozen individually and very quickly, but there is no distortion of their shape by pressure, and they thus retain the best possible appearance. Also most products retain a regular glaze on their exterior surfaces. The freezing time for shrimp and similar small fish require only a few minutes according to size, e.g. 6 to 12 min.

Earlier designs of fluidizing freezer comprised a perforated stainless steel trough along the length of the tunnel and the cold air passed upwards through this at the required velocity in relation to the product to ensure correct fluidization. Thus from the moment of entry from a feed conveyor or hopper to the point of exit, the product is continuously suspended in the air stream, and by adjusting the angle of the air stream, the rate of flow through the tunnel can be varied to suit the required freezing time.

Later designs of these freezers in certain applications have replaced the stationary fluidizing bed by a perforated stainless steel conveyor, sometimes also vibrating, which gives better control over some products (fig 11).

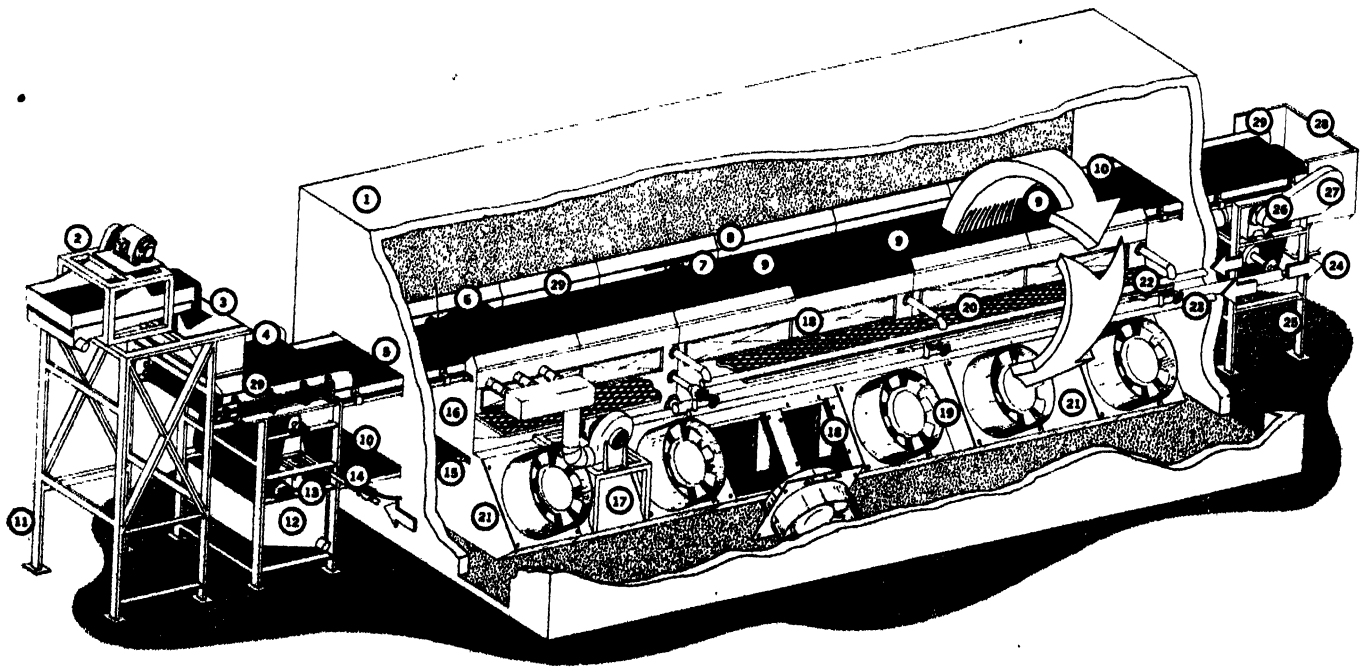


Fig 11. Lewis fluidizing freezer tunnel for loose products like shrimps, small fish, fillets, etc.

1. *Freezing tunnel chamber (insulated)*
2. *Primary dewatering shaker*
3. *Stainless steel metering hopper*
4. *Variable speed loading belt*
5. *Product entering freezing chamber*
6. *"Suspension booster". Supplies extra jets of air at these points to induce "low phase" suspension of products in the high velocity air stream*
7. *"Reload bar". Assures perfect redistribution of product at this point*
8. *Self-relieving stainless steel product guards. Ice cannot build up and damage conveyor*
9. *"Dense phase" suspension of product on conveyor belt—minimum fluidization for maximum freezing efficiency. No product damage and no loss of smaller particles*
10. *Balanced waste conveyor mesh with roller-chain drive. Since mesh is withdrawn from enclosure each revolution, cleaning and sanitation is simple and automatic*
11. *Prefabricated tail stand*
12. *Drain pan*
13. *Belt dryer nozzle*
14. *Automatic belt washing spray header*
15. *Return conveyor below evaporator coils*
16. *Evaporator coils located below product conveyor*
17. *High pressure air plenum and defrost water basin*
18. *Inspection doors*
19. *Recirculation fans—instantly adjustable through variable fan inlet vanes*
20. *Catwalk*
21. *Unitized sectional construction for ease of assembly, expansion or moving*
22. *Defrost water line can be arranged either for shift defrost or automatic sequential defrost for continuous operation*
23. *Refrigerant feed line to evaporator coils*
24. *Refrigerant return line from evaporator coils*
25. *Prefabricated head stand*
26. *Variable speed conveyor drive with remote speed changer and tachometer*
27. *Automatic torque clutch on conveyor drive*
28. *Stainless steel collecting hopper*
29. *Stainless steel trim at all product contact points*

So far as is known fluidizing freezers have not yet been used on board ship, but it is thought that they offer an attractive method for freezing several fishery products, which it would pay to freeze individually and pack after freezing. To be economical, however, a considerable throughput is desirable since typical sizes on land can freeze from 2- to 6-t/h. On the other hand these freezers are much more compact for a given output and require substantially less fan power, and hence compressor capacity. It is a simple matter to combine the fluidizing freezer with a conventional freezing tunnel arranged on the opposite side of the air coolers.

Air coolers and defrosting. The key to successful operation of air-blast freezer tunnels, especially of the continuous type, is the air cooler and many arrangements of these have been used to suit different requirements and shapes of tunnel. Since freezer tunnels necessarily involve two separate heat transfer processes, the first from the fish to the air and the second from the air to the refrigerant in the air cooler, space occupied by a tunnel freezer is considerably greater than with other methods. As the product cannot be reduced in volume and the air volume and velocities are virtually fixed for a given design, the only space economy which can be made is in the design of the cooler.

Ideally air coolers would all be constructed of plain pipe but, although these are quite often used, the space occupied in relation to a given cooling capacity is such that they are seldom practical on board ship, at least for larger tunnels.

Until a few years ago spirally-finned pipe was used, but nowadays most air coolers are of the plate-fin type, where the primary small-bore piping is arranged in staggered rows across the air stream and in intimate metallic contact with thin plate fins in the direction of air flow. These are preferably spaced at about 79 fins/m (2 fins/in), and it is important that there is the correct relationship between primary (pipe) and secondary (plate fin) surface; in the case of steel coolers the latter should preferably be bonded to the former by hot dip galvanizing after manufacture. Many air coolers have been seen where the secondary surface is grossly excessive in relation to the primary, and others have had the plate fins loose on the piping, so that virtually no heat transfer was possible. In current good designs the ratio between the total and primary surface areas is between about 5.3 and 6.5 for 79 fins/m (2 fins/in) and 7.5 and 9.0 for 118 fins/m (3 fins/in). The pipe banks also need to be at the correct pitch both in and perpendicular to the direction of air flow; triangular pitch is common, while other designs have slightly greater pitch perpendicular to the air flow. When selecting coolers of different designs it is not sufficient to compare only their respective total surface areas. Their configuration, primary pipe length and fin spacing are equally important. Too close a fin spacing must be avoided in freezing tunnels since space needs to be left for frost formation without unduly restricting air flow through the cooler.

It is prudent to assume a total to sensible heat ratio of 1.0 in freezing tunnel air coolers on account of frost formation, and it is important to design on reliable coefficients of internal heat transfer in relation to the refrigerant in use, system of circulation, and mean refrigerant temperature during the freezing cycle. Practical overall heat transfer rates for current good designs of gilled and plate fin air coolers vary between about 10.8 to 28.4 kcal/m.^{2} °C.h (2.2 and 5.8 Btu/ft.^{2} °F.h) for 79 fins/m (2 fins/in) spacing and in the refrigerant temperature range −40° to −34°C (−40° to −30°F), the highest figures being obtainable with pump circulation. Zaitsev (1962) advocates basing the cooling surface area on the cooling load during the TAP.

Defrosting of air coolers in batch freezers is usually possible after every one or two freezing cycles simply by allowing the cooler to warm up with doors open. However, for conveyor freezers or in cases where it is desirable to reduce the defrost time, water or hot gas defrost can be provided. Electric defrost is not, however, attractive in most cases on account of the power consumption required. For continuous freezers it is good practice to divide the cooler and fan capacity into, say, five equal sections and then to provide one extra section of equal size; it is then a simple matter to arrange that one section of cooler is always defrosting while the other five are in use. It is desirable that coolers are drained of refrigerant while defrosting, to reduce their heat capacity and so the time required.

Freezing with liquefied gases. In the past few years there has been a considerable study and application, particularly in the United States, of the so-called cryogenic gases to freezing, especially of such high-value products as shrimps. Initially this was by direct immersion in the liquefied gas, but for reasons which will be discussed later, this has given way to freezing in the vapourized gas and in a spray, on somewhat similar lines to a conventional air-blast freezing tunnel.

Liquefied gases which can be used include air (boiling point −194°C, −318°F), nitrogen (−196°C, −320°F) and carbon dioxide (−78°C, −109°F) (table 2). Until recent years none of these, except perhaps carbon dioxide, could compete commercially with conventional refrigeration methods, since naturally the cost of liquefaction increases rapidly the lower the temperature required. As there is no need in food freezing for the very low tempera-

TABLE 2. PROPERTIES OF SOME CRYOGENIC GASES

Name	*Chemical symbol*	R *No.*	*Boiling point* °C	°F	*Latent heat* Kcal/kg	Btu/lb	*Specific heat*
Nitrogen	N_2	728	−196.0	−320.4	47.4	85.6	0.248
Air	—	729	−194.2	−317.8	48.8	88.2	0.241
Methane	CH_4	50	−161.7	−258.9	121.4	219.2	0.593
Ethylene	C_2H_4	1,150	−104.0	−155.0	114.8	207	0.334
Nitrous oxide	N_2O	744A	−88.5	−127.0	89.8	162	0.2
Carbon dioxide	CO_2	744	−78.5	−109.3	136.8	246.3	0.202

tures associated with cryogenic liquids, other factors had to intervene to make cryogenic freezing remotely competitive.

The huge requirements for liquid oxygen in the United States space program, as well as to a lesser extent in increased steel production in many countries, has resulted in the availability of enormous quantities of liquid nitrogen as a by-product from the distillation of liquid air. The producers have therefore had to try to find uses for the liquid and gaseous nitrogen to cut their production costs for the primary product, liquid oxygen. While the price of liquid nitrogen is still high, it can compete in the freezing of more valuable products, because of certain advantages, and it is also quite cheap enough to make it competitive for maintaining storage temperatures in transport containers, whether by road or rail or perhaps barge. Liquid air machines are also offered both in the United States and in Europe for maintaining hold temperatures on board ship.

A typical nitrogen freezing tunnel for freezing, say, 900 kg/h (2,000 lb/h) of shrimps, fish fillets, etc., has a total length of 11.3 m (37 ft), including entrance and exit tunnels; the basic freezing unit is only 5.9×1.5 m (19.5×5 ft) wide × 1.85 m (6 ft) and 1,820 kg (4,000 lb) in weight. The product conveyor is contained in a double-walled, vacuum-insulated, open-ended cylinder, the ends of which are provided with high-velocity nitrogen gas curtains to reduce warm air infiltration. The speed of the conveyors is adjustable to suit the product. The product enters first a precooling section where cold gaseous nitrogen exhausted from the main tunnel is circulated over it to freeze the outside. This is continued in the first section of the main tunnel; in the second section liquid nitrogen is sprayed around the product and finally it enters the equilibrium section, where the temperature has a chance to equalize throughout the product. A fish fillet only remains in the freezer for about 3 min, and time must be accurately gauged to suit the product, both to prevent damage through excessively fast cooling, and to avoid cooling further than necessary. Economy depends very much on not wasting the liquid nitrogen. Liquid is recirculated through the tunnel by a pump from a tank below the tunnel, and this in turn is replenished from the large tanker vehicles in which the liquid is delivered.

The practicability of using liquid nitrogen freezing on board ship depends very much on the length of voyage, the efficiency of liquid storage to limit evaporation losses, the value of the product to be frozen and stored, and the overall capital and running costs in comparison with conventional refrigeration systems. There is considerable disagreement over cost comparisons, but a figure commonly quoted for land applications is that nitrogen freezing involves the evaporation of at least 1 lb of liquid nitrogen per lb of product frozen, and costs three to four times as much as conventional freezing methods. A simple calculation shows that this rate of evaporation is about right for cooling and freezing shrimp from around 13°C (55°F) to −29°C (−20°F).

Contact freezers

Contact plate freezers are probably the most efficient in current use at sea and two versions are common, the horizontal and the vertical types.

Horizontal plate freezers. As the name implies these freezers have their plates in the horizontal plane. Whole fish is contained in aluminium or steel trays with lids and these are placed between adjacent plates and maintained in contact with them by light hydraulic pressure, which can be adjusted to suit requirements. Horizontal plate freezers are commonly made in sizes varying from six or seven stations of 610×1,130 mm (24×45 in) to 20 stations of 1,780×1,120 mm (70×44 in). Normal opening between plates varies from 25 mm (1 in) to 75 mm (3 in), with up to 150 mm (6 in) for special applications. In any particular design the opening can usually be varied over a range of 50 mm (2 in), e.g. between 25 and 75 mm (1 and 3 in). For whole fish freezing on board ship a range from 50 to 100 mm (2 to 4 in) would probably be most convenient for most varieties.

Originally the freezer plates were normally of the Dole vacuum double-contact type, with a pipe coil held under vacuum in intimate contact with upper and lower steel plates. In recent years, however, these plates have largely given way for most applications to aluminium plates, built up from extruded section, which enable much better heat transfer rates to be achieved, and hence faster freezing. In one make the passages in the plates are drilled out of the solid.

The nest of freezer plates and their associated structure and hydraulic equipment are usually contained in an insulated cabinet, with heated double doors on front and rear to permit through loading. Many, however, have been installed for use in cold climates with no enclosure, both on board ship and on land, e.g. in Iceland, Norway and Greenland.

Single units are often arranged for direct expansion under the control of thermostatic expansion valves and freezing times with aluminium plates on 50 mm (2 in) blocks of whole herring are about 1 h 40 min; with steel plates this increases to 2 h. The evaporation temperature varies between about −10°C (14°F) and −37°C (−35°F) during the cycle, with an average between −15° and −22°C (5° and −8°F) depending on the type of plate and the product.

Most larger installations with aluminium plates now use pump circulation of the refrigerant at −34°C (−30°F) or lower, and under these conditions a 50 mm (2 in) block of herring will freeze in 1 h 10 min or less.

Automatic horizontal plate freezers are available for freezing consumer packs, loading and unloading being always at the same level, and the whole nest of plates rising and falling automatically as required to permit this. However, it is doubted whether this system could readily be adapted to whole fish, since trays are virtually essential to contain them and are usually rather large for automatic handling. Similarly the very large automatic horizontal plate freezers used in ice cream hardening and the like are unlikely to be suitable for whole fish blocks.

One design of automatic horizontal plate freezer, of which a prototype was made in the United Kingdom, might perhaps be suitable for freezing whole fish individually or in trays. This consisted of a stainless steel conveyor which passed over the lower plate and back below it. The fish entered from one end and the conveyor and top plate were synchronized so that every few

minutes the top plate lifted, the conveyor advanced a few inches, and the plate then dropped again.

Means are available for the mechanical loading and unloading of conventional horizontal plate freezers using tray racks on fork lift trucks. No doubt this idea could easily be adapted to a conveyor system.

Considerable work remains to be done on horizontal plate freezers, both to eliminate the need for trays to contain the fish and to mechanize the operation. There is also the question of defrosting and cleaning the plates, to ensure consistent conditions on all freezing cycles.

In ships, horizontal plate freezers are most suitable for fillets and certain small whole fish like herrings.

Vertical plate freezers. Following several years' development at the Torry Research Station, Aberdeen, of the Ministry of Technology, the first large-scale experimental vertical plate freezer plant was installed in 1956 in the old steam trawler *Northern Wave*. This led, in 1961, to the first full-size commercial installation in the stern trawler *Lord Nelson*. Freezers of another make were fitted in the *Junella* the following year, and a completely new design was developed for the Icelandic side trawler *Narfi* which was converted to a freezer trawler in 1963.

It is probably true to say that all the later designs of vertical plate freezer so far used at sea have been based on the *Narfi* freezer, and this in turn was essentially an adaptation of well-proven practice with horizontal plate freezers, together with the aluminium extrusion plates first used in the *Lord Nelson*.

The original purpose of developing the vertical plate freezer was to provide a means of freezing Arctic white fish which involved as little change as possible compared with the traditional methods of preparing and icing fish on board British distant water trawlers. Freezer station sizes were therefore selected which suited the majority of cod and haddock caught on the Arctic grounds and also as large as could conveniently be handled by one fisherman for stowing in the hold. The size chosen for the *Lord Nelson*, 1,070 × 535 × 102 mm (42 × 21 × 4 in) thick, which has since been used as a standard in several designs, also corresponds to the length of the pound boards in that vessel. Although the blocks produced in the later freezers have averaged as much as 53 kg (116 lb) in weight for gutted headed cod or haddock, fishermen have been seen handling two at once, so that they are obviously not too heavy. It will be clear that the larger the block size chosen for a given thickness, the more compact will be the freezer, and this is of paramount importance on board ship. Other block sizes which have been used are 1,000 × 1,000 × 150 mm (39 × 39 × 6 in) in the Argentine and 800 × 400 × 80 mm (32 × 16 × 3 in) weighing 22 kg (48 lb) for herring in the largely automated system in the East German *Ostsee* class stern trawlers.

All vertical plate freezers are designed for loading from above, but unloading can be arranged in any direction to suit the layout in the vessel (fig 12). The *Lord Nelson* freezers dropped the blocks out through the bottom into racks situated in the fish hold, and a similar arrangement has been adopted in the *Arctic Freebooter*. The *Narfi* freezer was provided with a hydraulically-operated bottom platform which lowered the blocks directly into the hold and also formed an insulated plug hatch in the deckhead when

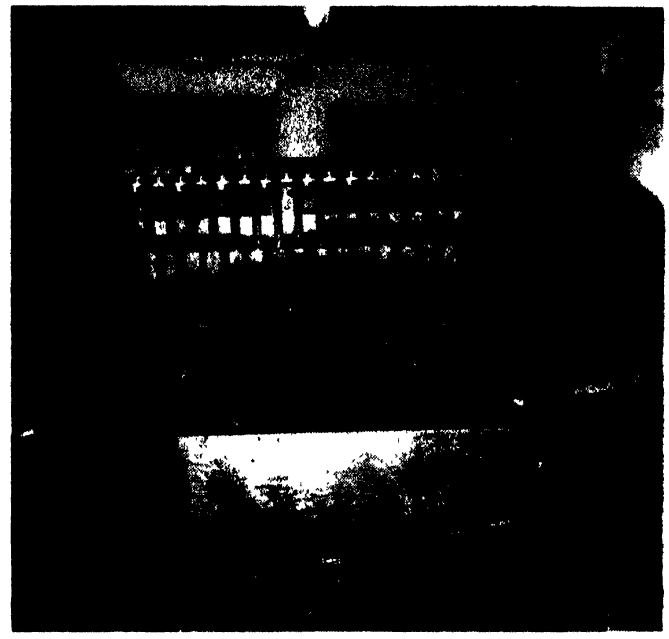


Fig 12. Twenty-station top-unloading vertical plate freezer in Argentine octopus freezer stern trawler Puerto Madryn

in the up (freezing) position; this type was also used in the Korean factory vessel *Back-Dusan*. A similar arrangement was used in the Dutch *Egmont*, where a complete crop of blocks was dropped together at the end of each freezing cycle. An idea proposed originally for the *Arctic Freebooter* involved lowering the blocks into the hold on a platform below each freezer and sweeping the blocks off on to an elevator from which they could be stowed anywhere in the hold. An adaptation of this idea has been adopted in the *Ostsee* class vessels (fig 13), where the blocks drop out by gravity into a rack below the freezer and are then pushed hydraulically on to a conveyor which takes them one by one through a spray glazer before packing and storage. One of the advantages of dropping the blocks by gravity is that it is not necessary to remove them before refilling the freezer for the next cycle. Where they drop directly into the hold the space below each freezer can be used for storing blocks at the end of the fishing period to fill the hold completely.

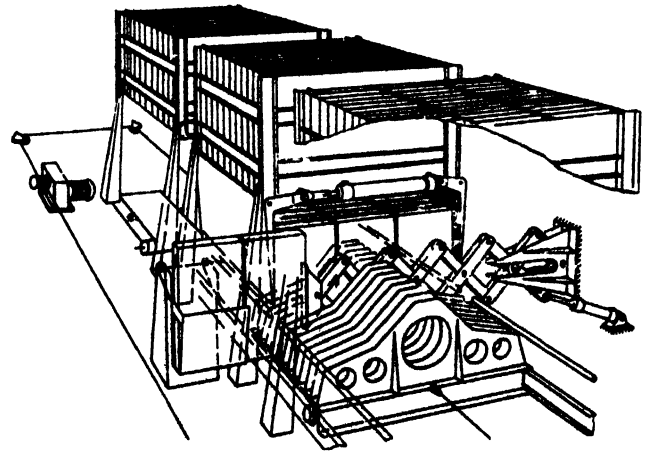


Fig 13. Automatic vertical plate freezer in Ostsee-*class herring stern trawlers (East Germany)*

Probably the greater number of freezer stern trawlers with vertical plate freezers discharge the blocks horizontally on the same side as that from which they were loaded. From there they are taken by hand, conveyor and/or chute for stowage. In the *St. Finbarr*, recently lost off Greenland, the blocks were originally intended to be discharged from the opposite side, the rear doors of the freezers opening directly into the fish hold at an upper and lower level; roller conveyors were used to take the blocks forward for stowage.

Another solution which has been used, especially where little space is available, is to discharge the blocks upwards hydraulically, from where they are removed for stowage. This method is also used for fillet freezers, where in addition a top plate is provided which is brought down hydraulically to form the tops of each station; cartons can also be inserted in each station before freezing, if desired. Top discharge models have two advantages over the other types. Firstly, it is easier to use portable dividers to produce smaller blocks, if needed for certain species, and secondly the stations can be filled neatly by lowering the forks slowly from the top position until full. A similar model is also available where two different thicknesses of block can be produced, simply by changing the end plates and adjusting the hydraulic mechanism.

An automatic vertical plate freezer is available in the United States for dealing with small consumer packs, e.g. for hardening ice cream.

The great advantage of vertical plate freezers is that no trays are needed, their operation is simple, and a considerable degree of mechanization is possible, all of which are important on board ship. For a given output they also require less space for installation and operation than any other freezer at present at sea.

Vertical plate freezers operate best on the pump circulation of a primary or secondary refrigerant. The *Lord Nelson*, *Narfi* and *Praia de Ericeira* class use Refrigerant 12 in the freezers; the *Maria Teixeira Vilarinho*, *Santa Isabel*, *Santa Cristina*, *Cidade de Aveiro* and *Puerto de Madryn* class use Refrigerant 22, various German vessels and the Korean *Back-Dusan* use calcium chloride brine and most British trawlers now use trichlorethylene. In all cases provision is made for hot gas or hot brine for defrosting, which is an essential feature with vertical plate freezers if correct block densities and shortest freezing times are to be achieved (Merritt and Templeton, 1963).

With a refrigerant temperature of −40°C (−40°F) and the optimum circulation rate freezing times as low as 2½ h have been recorded on 100 mm (4 in) blocks, but for a full-scale plant a more prudent average time to use in calculating freezer size for a given throughput is 3 h freezing time and 3½ h freezing cycle, the latter varying slightly according to the type of freezer.

The desirability of splitting the freezer capacity into a considerable number of equal sections has been explained in connection with freezing tunnels. This is equally important with vertical plate freezers. Common installations comprise six, eight or ten freezers, each with 12 stations, and these are loaded in sequence in relation to the freezing cycle, e.g. with a 200 min (3 h 20 min) cycle and eight freezers, one freezer would be emptied and reloaded every 25 min. As defrosting is an essential part of every freezing cycle, no time is lost and the freezers can work continuously all the time there is fish to freeze. With this method of operation the refrigerant temperature remains virtually constant at the designed level, and there is therefore no fluctuation in compressor loads and hence power requirements from the ship's generators.

In small vessels where only one or two freezers are required, a pump circulation system may be difficult and inordinately expensive to instal, on account of lack of space and height. In such cases either a gravity system or thermostatic expansion valve control are the only alternatives. With both of these the freezing time will be much longer, e.g. 4½ h for a 100 mm (4 in) block, so that the freezer for a given output will be larger. There is also difficulty in providing sufficient hot gas for defrosting when only one freezer is installed, and an auxiliary electric evaporator may be needed in addition to the heat available from the hold cooling system. It is desirable not to separate the hold refrigeration from the freezers, since each can assist the other. It is important to recognize that compromises have to be made in small ship installations, which produce acceptable results even if they are not ideal.

Criticism has sometimes been levelled at the vertical plate freezer on two counts. Firstly the appearance of the blocks, with the irregular shapes and arrangements of the fish in these, is not attractive, and secondly some delicate varieties are said to be damaged by the pressure applied to them during freezing. There is no doubt that the appearance of the frozen blocks is irregular and poor compared with those produced in trays or boxes in tunnels or horizontal plate freezers. However, experience has amply demonstrated that the quality of the fish when thawed is equal or superior to any frozen by other means, and the large blocks are in any case not intended to pass beyond the wholesaler in the distribution chain. In other words the fish trade can be educated to recognize the advantages and superior quality of fish from vertical plate freezers, and must also be encouraged to alter its methods of handling so that the retailer and consumer receives an attractive product, whether as whole fish, steaks or fillets, packaged or not, to suit the market.

With regard to the second criticism, no first-hand evidence has been seen of any damage to fish frozen in vertical plate freezers, as compared with any other method. With the designs of freezer in common use, the hydraulic pressure on the plates is adjustable, and only very light pressure is normally used simply to maintain contact between the plates and the fish as it expands during freezing. Fish at the bottom of the block have to support the weight of all the fish above them, but this is no worse than when they are stowed in bulk in ice. The important thing is to handle the fish properly in reprocessing and distribution, and to thaw them completely before handling or straightening them.

Radial plate freezer. A novel plate freezer is the radial design developed in the U.S.S.R. with a freezing capacity of 8-t/day and producing blocks 400×250×60 mm (16×10×2½ in) and weighing 6 kg (13 lb). The freezing time to −25°C (−13°F) in the centre is 2h 18 min with refrigerant at −32°C (−26°F). This freezer is loaded and unloaded automatically.

Rotary drum freezer. A novel adaptation of the revolving drum flake ice maker has recently been developed for the individual freezing of shrimps, fillets, etc. (fig 14a). These are fed by a conveyor on to the external surface of a revolving stainless steel drum held at a low temperature. Here they immediately adhere by the freezing of water. At the end of one revolution the frozen product is scraped off on to a conveyor and passed through an automatic glazer for packaging. As there is no air movement and freezing is very rapid, the makers claim that there is no loss of weight during freezing.

Immersion freezing

Freezing in brine. At first sight one would expect immersion freezing to be the most efficient and simplest method for fish. Intimate contact is assured between every surface of the fish and the freezing medium, and therefore good heat transfer appears certain with proper design. Unfortunately this has not proved to be the case in practice. The only freezing medium which has found favour is sodium chloride brine and this has a eutectic point of −21.2°C (−6°F), which means that it cannot be used much below −18°C (0°F). Also there are practical problems affecting installations on board ship, where a compromise must usually be made between the use of the tanks first for freezing and then for storage, so as to avoid double handling; this is in addition to their use in some vessels for fuel storage on the outward voyage and also as bait tanks. Even where this is not the case, best conditions are seldom achieved due to space or other considerations.

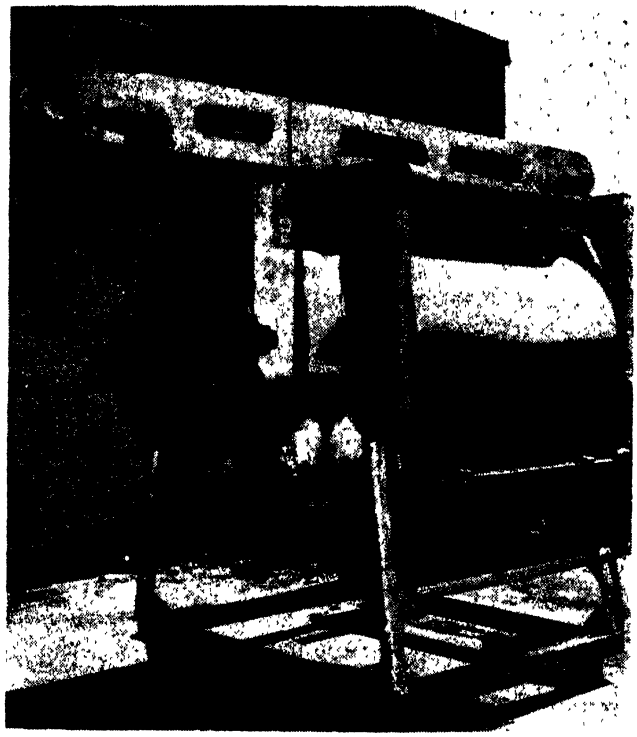


Fig 14(a). Wentworth rotary drum freezer for individual freezing of such products as shrimps, fillets, etc.

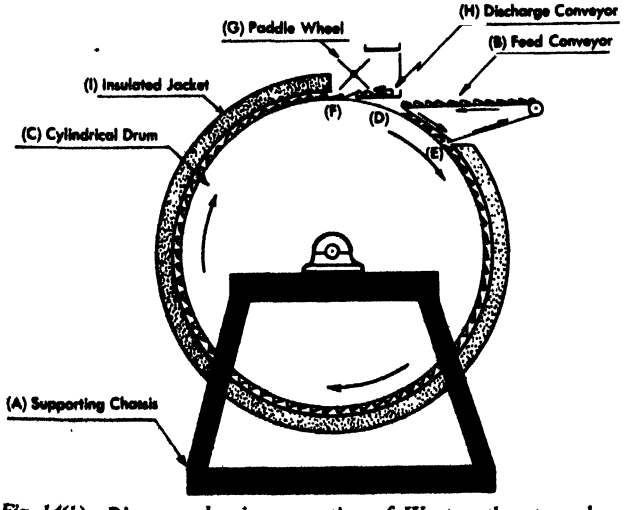


Fig 14(b). Diagram showing operation of Wentworth rotary drum freezer

It is interesting to recall the early British patent No. 6117 granted to E. Hesketh and A. Marcet on 9th April 1889 and covering the direct or indirect immersion freezing of fish and other products in cold brine.

Brine freezing has been used almost universally in the U.S. west coast tuna purse-seiners, delivering their catches to the large canning factories after three- to four-month voyages. Brine freezing is also used for sardines and shrimp and has also been suggested for mackerel and herring. Although brine freezing was reasonably successful in the U.S. research vessel *Delaware* on white fish, the method has not been adopted commercially for these varieties.

Experience in the U.S. tuna industry has led to the adoption of brine freezing in other countries, including the tuna clippers built in the United Kingdom for Ghana, others for Spain, France and Portugal, and the recent Spanish *Sarasua* with its ingenious arrangement and considerable mechanization (fig 15). It is interesting, however, that for the most part the Japanese preference is for air-blast freezing of tuna, much of which is sold directly and not passed for canning.

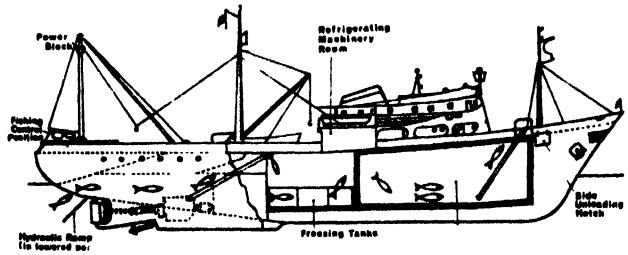


Fig 15. The Spanish tuna purse-seiner Sarasua

Brine freezing as normally used on board the U.S. tuna vessels involves stowing the tuna as it is caught in one of a number of tanks built into the after part of the vessel on either side of the shaft tunnel; the size of individual tanks may vary from about 30- to 60-t capacity depending on the size of vessel, which in turn varies between as low as 200-t total capacity in older vessels and 600- to 800-t in some modern designs (Logan, 1965).

Each tank is lined on all surfaces with ammonia direct expansion cooling coils usually of 32 mm (1¼ in) N.B. pipe on 150 mm (6 in) centres of a length equivalent to about 10.8 to 11.9 m/m³ capacity of tank (1 to 1.1 ft/ft³). Since tuna are normally stowed at a rate not exceeding

800 kg/m³ (50 lb/ft³), a 60-t tank is about 75 m³ (2,640 ft³) and therefore requires up to 880 m (2,900 ft) of pipe coil. When this is multiplied by say, 10 tanks, it will be appreciated that a huge length of cooling coil is needed and this is all subject to some of the worst possible conditions for corrosion. Careful galvanizing and protection with non-corrosive paints is therefore essential on all piping and fittings in the tanks.

Each tank is also provided with its own brine circulation pump which should be of sufficient capacity to give a fairly rapid circulation of the brine over the coils and through the fish. Older vessels used to have a circulation rate equivalent to 45 l/min/t of fish stored (10 gal/min/t) but this is much too low for good heat transfer and also the practice has always been to circulate downwards, whereas ideally the brine should circulate upwards at a velocity just sufficient to keep the fish in suspension in the brine. Even with the present system, heat transfer rates from the fish of about 48.8 kcal/m.² °C/h (10 Btu/ft.² °F.h) are achieved and the figure for the coils is 48.8 to 73 kcal/m.² °C.h (10 to 15 Btu/ft.² °F.h).

A method advocated by Slavin and Smith (1963) for improving the system is by using an external brine cooler of the shell and coil type where a heat transfer rate of 146 to 196 kcal/m.² °C.h (30 to 40 Btu/ft.² °F.h) can be achieved and the rate of brine circulation should be such as to have a brine temperature rise of 1.7° to 2.8°C (3° to 5°F) through the cooler under maximum conditions. Cooling coils are still required either inside or surrounding the tanks to deal with heat leakage, but much faster cooling of the fish can be achieved. An additional refinement put forward by Slavin and Carlson (1963) allows a very close control of brine temperature to be obtained by means of an automatic hot gas by-pass control on the compressor; this can also be used to provide hot brine for thawing at the end of the voyage. They also advocate the use of Refrigerant 12 instead of ammonia in the refrigeration plant.

The conventional method of cooling and freezing tuna is to cool it first to as near −1°C (30°F) as possible in chilled sea water at the same temperature. Salt is then added to the sea water at a rate of about 50 kg (110 lb) salt/t of fish to produce a brine of about 1.126 specific gravity and with a freezing point of −13.5°C (8.2°F). The brine and fish is cooled until the fish reaches −7.8°C (18°F) or lower. The brine is then drained out of the tank and the fish is cooled and stored dry at a temperature as low as possible, and not higher than −12°C (10°F). Each operation takes about 24 h on normal sizes of tuna. In later vessels, lower brine temperatures are used and the fish may be cooled to −15°C (5°F) before draining the brine. One owner found that better and faster results could be achieved by mixing and precooling the brine before any fish was caught and then doing the cooling and freezing in one continuous operation. This should reduce salt pick-up by the fish. The Japanese report the need to store tuna well below −20°C (−4°F) to retain quality and colour, especially in the inner layers. They recommend −35°C (−31°F) (Ogawa, 1967).

Brine freezing has been used successfully at sea for Gulf of Mexico shrimp (Dassow, 1954) and results were fully comparable with shrimp frozen at sea in an air-blast freezer, and greatly superior to any landed in ice. Freezing times for even the largest headless shrimp did not exceed 15 min from about 2° to below −10°C (35° to 15°F). Care is required in glazing, packaging and storage at −18°C (0°F) or below, to avoid dehydration because of the irregular shapes resulting in unavoidable air spaces in the packs. The system has also been used in other countries, but rather surprisingly is not common, plate freezers or air freezing, not necessarily in tunnels, being preferred. Rock lobsters have also been frozen in brine at −20°C (−4°F) in perforated aluminium containers with a capacity of 9 kg (20 lb). The freezing time from 16° to −18°C (60° to 0°F) was 165 min, compared with 18 h in shelves or an air-blast. After freezing the frozen blocks are transferred to cartons. Brine freezing of crustaceans is also reported from Australia.

The handling of products after freezing in brine and then storage dry is often difficult and messy, especially for small fish like sardines and mackerel. There may be a case for some larger products to use polythene bags as is common for poultry.

It was stated at the beginning of this section that other freezing liquids would be preferable to sodium chloride brine. One of these, which is advocated by Slavin (1964a) and is also acceptable as a food additive at least in the United States, is a 50 to 50 solution of propylene glycol and water with a freezing point of −32°C (−25°F). The freezing time for an average 45.5 kg (100 lb) tuna is 18 h in this solution at −29°C (−20°F) compared with 30 h in brine at −18°C (0°F). There is also negligible pick-up of this fluid during normal freezing. Its only drawback is its comparatively high cost.

Brine-spray freezing. George Mudd used brine spray freezing in 1900 for Dover sole and turbot to be exported to the United States. Other variations of this method followed in the 1920s and early 1930s. The U.S. tuna clippers used a form of brine spray freezing, but it was totally inadequate in comparison with the later immersion system now universal in the purse-seiners.

Freezing in liquid nitrogen. Some years ago there were many advocates of ultra-rapid freezing by direct immersion in liquid nitrogen at −196°C (−320°F). Very soon it became clear, however, that while virtually instantaneous freezing was achieved compared with any other method, the internal stresses generated in the interior of the product were such as to make direct immersion unacceptable at least for fish (Lorentzen, 1964). This led to the experiments at the Torry Research Station with liquid carbon dioxide, and alcohol and trichlorethylene each mixed with dry ice, as well as with liquid nitrogen, which established the maximum rate at which white fish can be cooled without incurring structural damage (Merritt, 1966).

Freezing in liquid Refrigerant 12 (Dichlorodifluoromethane). An interesting recent development in the United States is the freezing of high value products by immersion in Refrigerant 12. The heat transfer rates are stated to be double those for liquid nitrogen and costs are likely to prove much lower (Slavin, 1967). As the boiling point is only −30°C (−22°F), no difficulties arise with internal damage to the fish, though the method

still needs clearance on health grounds to enable it to be used commercially. It will be interesting to see whether means are found for recovering the refrigerant, which should reduce very markedly the already quite reasonable cost of this method.

It is interesting to note that Professor N. S. Komarov put forward a scheme for immersion freezing in liquid carbon dioxide as long ago as 1926. Presumably this was not pursued because of the difficulties in handling and high pressures associated with carbon dioxide (Zaitsev, 1962).

FREEZING AT SEA OF WHOLE FISH IN PREFERENCE TO FILLETS

Argument is almost continuous on the question of how far fish should be processed on board ship as soon as possible after catching, and in relation to the requirements of the market. It is indisputable that every man or woman employed on board ship is far more costly and usually less productive than in a shore factory, and the conditions of work are inevitably more difficult and less conducive to the maintenance of high standards of handling, hygiene, etc. The quality of the final product cannot be guaranteed unless there is good discipline and proper attention to good practice in the catching, handling, preparation, processing, washing, buffer storage and freezing and stowage of the fish. This discipline cannot be maintained if the capacity of the production lines is swamped by heavy catches (Eddie, 1967).

The Japanese and Soviet fleets employ almost every conceivable variation of processing line from simple whole fish freezing plants with manual gutting and heading, to the most extensive factory vessels employing a multitude of types of gutting, heading, filleting, freezing, canning, fishmeal and oil extraction equipment, together with a large measure of mechanization of handling between and during each process; the Polish, East German and Rumanian fleets have followed a similar pattern. However, apart from a few isolated examples, only one other country, West Germany, has so far adopted similar mechanization and concentrated on landing sea-frozen fillets. In the United Kingdom there are only the three Chr. Salvesen *Fairtry* factory stern trawlers, and the three Ranger Fishing Co.'s middlewater trawlers. A few others exist in France, Belgium, Norway, Italy, Spain and one or two other countries.

By far the largest number of freezer vessels have been equipped solely for freezing whole fish at sea and it seems pertinent to examine some of the reasons for this preference, which at first sight may appear surprising. Most of the following remarks apply particularly to the varieties of white fish and red fish caught mainly in northern and southern waters, but they also apply to a greater or lesser extent to all commercial varieties.

Fish comprises guts, heads, tails, skeletons (or shells), and in certain cases livers and oil, as well as the flesh itself, usually in the form of fillets or steaks, which is the most valuable part in terms of food value and commercial profit on the market. Since freezer vessels for the most part have to make long voyages, it would appear logical to bring back only the most profitable fish products, provided of course that these suit the market concerned.

Unfortunately, no figures appear to have been published giving a comparison between the costs of fillet

TABLE 3. WHOLE FISH VERSUS FILLET FREEZING IN FISHING VESSELS AT SEA

Whole fish freezing		*Fillet freezing*	
For	*Against*	*For*	*Against*
Less degraded product	More weight and volume of fish saved—larger holds	Less weight and volume of fish saved—smaller holds	Need for sophisticated market to accept product
Product usable in existing market system as fresh fish	Little material available for fishmeal plant on board	All rubbish and offals available for top quality fishmeal	Thawing and reprocessing required in factory on land
Product usable as raw material in factories on land for all traditional purposes	Larger freezing and cold storage plant	Smaller freezing and cold storage plant	*OR* Large blocks have to be cut up with consequent 8–12 per cent loss
Excellent appearance when thawed	More refrigeration required	Less refrigeration required	Need for manual filleting of sizes and varieties outside scope of machines
Top quality fishmeal from residue on land	Need for thawing and refreezing on shore for producing consumer packs	*FUTURE*	Difficulty of machine handling of live, *pre-rigor* or *in-rigor* fish
Simpler equipment		Possibility of producing consumer packs	Discolouration of fillets with blood
Lower capital cost			Swamping of machine capacity by large catches
Low maintenance costs			*OR* Under-utilization of machines, aggravated increasingly by declining catching rates
Lower running costs			Productivity no higher except in much larger vessel
Little change in crew size—may even be smaller			Difficulty of maintaining quality and hygiene, especially with heavy catches
More flexibility to deal with heavy catches and any variety			Complicated equipment
Productivity of vessel similar			High capital cost
Appearance of thawed product better than of thawed fillets			High maintenance costs
			Larger space occupied by machines
			Much larger crew and hence more space on board for accommodation, amenities, stores, etc.
			Much higher operating costs of vessel
			Usually longer voyages resulting in difficulty in obtaining and retaining good crew
			No better price for product

versus whole fish production at sea, so that in this discussion we must perforce rely mainly on technical and practical considerations, but it is thought nevertheless that these show definite advantages for freezing whole fish at sea, in the context of nearly all existing commercial fisheries operations, which must of course include every stage from catching to the ultimate consumer.

It should be stated, however, that these advantages apply to the present stage of technical development, when it is still impossible to produce consumer packs economically at sea, simply on account of the amount of manual labour which continues to be required. This is due to the lack of processing equipment capable of removing pin bones from the fillets, of fully adequate weighing machines able to operate accurately in a violently rolling ship, and of suitable packaging machinery. All these machines are under development, and may soon change radically future thinking on how far to process fish, or at least the commoner commercial varieties, before freezing at sea (Diestel, 1967).

The main argument in favour of factory trawlers is that one is dealing with an absolutely fresh and sometimes even a living raw material, so that it should be possible to produce a top quality fillet or other product from it. Also, since only eatable portions of the fish are retained, the weight and volume which has to be frozen and stored is reduced in the case of fillets, to some 42 per cent and 31 per cent respectively for whole gutted cod, and to 58 per cent and 46 per cent for gutted headless cod; the reductions are even more spectacular for hake and red fish. Less than half the thickness is involved in freezing fillets as compared with whole fish. In addition, the offal, bones, etc., and much unsaleable fish can be reduced to top quality fish meal, equivalent to about 12 per cent of the weight and some 13 per cent of the volume of the original whole fish (Anon. 1965). This results in much smaller holds for a given catching rate and voyage length, and freezers occupying very much less space, e.g. a blast freezer for cod fillets needs to accommodate less than 14 per cent of the weight of gutted whole fish or less than one-fifth of the weight of gutted headless fish.

The objections to filleting at sea are the complication and cost of the processing machinery lines, the number of different lines needed to accommodate different varieties and sizes, the under-utilization of the machines, due to the wide fluctuation between maximum and average throughputs, which is aggravated by declining average catching rates, the need to deal manually with sizes outside the ranges of the machines, the larger crew required to man the factory, the increased space required for the processing machinery and crew quarters, amenities and stores, the need in almost all cases for additional processing on shore before marketing, and the relatively fixed and sophisticated market chain needed to handle the products. A British design study shows that productivity per ship is no higher for fillet than for whole fish freezing until the length greatly exceeds 73 m (240 ft) and this is not off-set by any premium or even subsidy payable for any higher quality of sea-frozen fillets in comparison with those from shore factories. The same study showed that the crew size for fillet production would be 44, compared with 24 in an equivalent British whole fish freezer vessel (OECD 1965; Eddie, 1964). All the above factors contribute to the very much higher capital and running costs of factory trawlers.

Other difficulties which arise are in dealing with live or *in-rigor* fish, discolouration of fillet blocks through inadequate bleeding before freezing, the maintenance and cleaning of the processing machinery, obtaining factory workers of the required standard in competition with the easier working conditions and hours for similar work on shore, the additional social and perhaps replacement problems of larger crews, aggravated in the larger vessels by longer voyages, and losses of 8 to 12 per cent by cutting large blocks into fish sticks as an alternative to thawing and reprocessing. In addition, fish meal production has sometimes proved unprofitable at sea due to wide fluctuations in world prices.

As at present produced, whole fish is only gutted and, in an increasing number of cases, headed, before being frozen individually or in blocks, as soon as possible after catching. It is often alive when gutting commences and, except at times of exceptionally heavy catching, can normally be placed in the freezers well before the onset of *rigor mortis*. Whole fish frozen at sea is therefore in a less degraded form than fillets, or even the best iced fish from distant waters, and when thawed is almost indistinguishable from very fresh fish; it is demonstrably superior to iced fish, having a translucent firm appearance compared with the bleached and usually soft condition of most iced fish. In consequence sea-frozen whole fish can be presented to the consumer in any of the traditional forms, and will almost always be superior in quality to the same product produced from iced fish. As fish frozen at sea immediately after catching can be stored at −29°C (−20°F) almost indefinitely, whole frozen fish offers great flexibility in meeting all market demands, especially in times of scarcity of wet fish landings. It may be thawed and sold as fresh fish on ice, it can be smoked or kippered, it can be filleted and if necessary refrozen into consumer packs of fillets, fish sticks, or what you will. It could no doubt be salted or dried (Baxter, 1964), if the demand existed, and would certainly be of greatly superior quality to any produced by traditional methods. It is ideal for canning, e.g. in the sardine and tuna industries. Thawed whole fish, therefore, enables existing marketing patterns to continue unaltered side by side with the development and establishment of new methods. Offal and rubbish can go for fishmeal to produce a quality greatly superior to that currently obtained on shore from condemned fish and the offal, etc., of iced wet fish.

There is a marginal benefit in freezing *pre-rigor*, which is easier with whole fish, though it should then be stored for a minimum of eight weeks at −29°C (−20°F) to pass through *rigor* (OECD 1965); the latter can, however, be accelerated by holding at about −5°C (23°F) for a few hours before complete thawing. Smoking of thawed whole fish is much easier and more consistent than of thawed fillets. Other advantages are the simpler equipment required, and the smaller crew needed to handle a given catching rate; with good mechanization it is even possible to reduce the crew size. Capital, running and maintenance costs are therefore lower for whole fish freezing vessels than for fillet freezers. If a longer voyage is considered possible from the crew point of view, it is a simple and comparatively cheap

matter to provide a larger frozen fish hold with little if any change in propulsion power and much less increase in fuel, stores and victuals than in the case of a factory trawler.

The main disadvantage of freezing whole fish at sea is that we are freezing, saving and storing a lot of uneatable portions of the fish; some people would call these rubbish. It is for this reason that heading is normal in addition to gutting, and in some modern vessels is done by machine. Heading reduces the weight of cod by 30 per cent and of hake by 45 per cent. Red fish on the other hand is usually frozen whole without even gutting, on account of the difficulty of handling it manually.

Thawing and reprocessing of whole fish blocks is essential in most markets, except where thawed whole fish, or steaks from blast frozen blocks are the only requirements. This naturally involves additional capital and running expenses on shore in providing thawing and freezing plant, but these must also be incurred for most fillet blocks, though it has been claimed that 50 per cent more refrigeration is needed for whole fish. Considerable research has been done on the effects of thawing and refreezing of fish, and the conclusion is that any deterioration in quality which occurs is negligible, especially in relation to an already superlative product (MacCallum *et al.*, 1966, 1967; MacCallum and Sepic, 1967; Peters *et al.*, 1968). Lorentzen states that "no appreciable difference in organoleptic quality could be detected in fish frozen one, two, three or even five times. It may therefore be concluded that frozen raw material may safely be used by the fish fillet industry" (Lorentzen, 1965).

Above all, freezing whole fish at sea transfers all the most expensive operations to shore factories where space is not at such a premium and workers (mainly women) can be employed more cheaply and continuously than at sea. The last word should perhaps go to Mr. John Ross, of Ross Group, Grimsby: "One speaker said that we ought to be able to produce machines to fillet fish at sea because we are now producing machines to get us to the moon. I would agree with that, but nobody has actually got to the moon yet at a profit, and this is the only thing we are trying to do in fishing from Britain. . . . We have decided that the key to a successful operation is to keep it as simple as possible. . . . With freezing whole fish there is very little that can go wrong" (Anon. 1965).

CONCLUSIONS

In this paper an attempt has been made to survey the best current practice and thinking in the freezing of fish, and especially whole fish, at sea, and to give a considerable amount of technical data as a guide to owners in the selection of the right equipment, even if it is not always the cheapest. Since the freezing process occupies such a small part of the total time between catching and consumption, considerable space has been given to preparation for freezing, treatment afterwards, and above all the maintenance of correct storage conditions throughout the distribution chain. The size of freezing plant required has also been given some prominence, since so many vessels are fitted with unrealistically large plants. It must be stated, however, that the cost of refrigeration by most current methods is low in relation to its function on board ship and to the ultimate selling price of the product (OECD 1965; Rasmussen, 1967); it is therefore, a false economy to instal plant of inadequate capacity, and then to limit the time in the freezers during periods of heavy catching. Freezing at sea should always be completed correctly, even if occasionally this necessitates considerable buffer storage and even the suspension of fishing operations. Incorrect freezing procedures can cause irreversible damage to the fish products, and refrigeration only retards, but can never arrest deterioration.

"Freezing at sea means many different things" (OECD, 1965), and it is difficult to generalize. Part-freezer vessels may appear attractive in some fisheries with short voyages, e.g. from Canadian and United States east coast ports, whereas they have been dropped in others like the British and F. R. German. Freezing comes more and more into its own the longer the voyage and the lower the catching rates.

Research still needs to be done on many aspects of freezing at sea, especially of new or unusual commercial varieties. Problems which exist in some fisheries include the freezing of certain species ungutted, the apparent oxidation of the oil content of some oily fish during or following freezing in some seasons, the effect of feeding habits on frozen fish quality and storage life, the possibilities of combining irradiation, antibiotics and/or possibly inert gas (nitrogen or carbon dioxide) with refrigeration for some varieties, together with any safety factors involved in these, etc.

Apart from normal improvements in design, handling and mechanization, possible future developments might include freeze-drying at sea of certain varieties and dehydrofreezing (Slavin, 1964b), the use of liquid nitrogen or air and immersion freezing in Refrigerant 12. Drying as such is perfectly feasible (Baxter, 1964) but appears hardly in line for most markets with the aim of landing the fish in a form as close as possible to fresh fish as caught; on the other hand drying simplifies distribution in some developing tropical countries where an internal chain of refrigerated lorries, cold stores, etc., does not exist. Liquid nitrogen may find a place at sea and proposals have been made for installing liquefaction plant; in the latter case, however, liquid air appears more attractive as the distillation column and maintenance of gas purity are largely eliminated. Production costs of liquid nitrogen or air at sea, which are 20 to 40 times those involved in using normal refrigerants, would seem to preclude their long-term use, except if supplied from shore factories as by-products, and this would appear to apply only to liquid nitrogen. Immersion freezing in liquid Refrigerant 12 appears very attractive for the future, especially if it can be recovered and reliquefied. Otherwise all these expensive methods can only be justified for high-value products like shrimp, lobster and certain other shell-fish, and only on short voyages in small vessels.

Freezing at sea is already a major industry in many industrialized countries. It is to be hoped that it can contribute substantially to the world's most formidable problem of feeding the exploding populations in many developing countries, especially in tropical areas. It is for engineers and naval architects to work closely with scientists and others in many fields, both individually and through specialized organizations like FAO, to combat world hunger by all possible means.

References

AKERMAN, A 1964 La evolución del pesquero de arrastre de altura en los últimos cuatro años. *Ingeniería nav.*, **32**, 353.

AKERMAN, A 1966 Freezer fleet in six years. *Wld Fishg*, **15**(10), 67–68.

ANON. 1960 Installation de congélation rapide. *Navires Ports Chant.*, February.

ANON. 1965 *Fish Quality at Sea.* Proceedings of the Conference on the design of fishing vessels and their equipment in relation to the improvement of quality of fish. Ed. *Wld Fishg* and White Fish Authority, London, Grampian, 129 pp.

ANON. 1965a Quick freezing of fish. *Torry Advis. Note*, No. 27, Torry Research Station, Aberdeen.

ANON. 1965b Packing company scores again: starts liquid nitrogen freezing. *Fishg Gaz.*, **82**(4).

ANON. 1965c New cryogenic system for "ultrafast" freezing of food products. *Mod. Refrig.*, **68**(805), 335–338.

ANON. 1966a Liquid gas and fish freezing. *Wld Fishg*, **15**(5), 55–56.

ANON. 1966b What liquid nitrogen freezing means to the seafood processing industry. *Fish Boat*, **11**(4), 27–32, 70, 77–78, 81.

ANON. 1966c Biggest liquid nitrogen shrimp freezer. *Food Processing and Marketing* (Chicago), **27**(3), 48–50.

ANON. 1966d Don't overlook carbon dioxide. *Food Processing and Marketing* (Chicago), **27**(3), 67–68.

ANON. 1967a Une série de 102 navires-usines construits en Allemagne orientale pour L'U.R.S.S. *Pêche marit.*, **46**(1069), 263–267.

ANON. 1967b Installations automatisées sur le chalutier congélateur harenguier du type "Ostsee". *Pêche marit.*, **46**(1069), 247–250.

ANON. 1967c Automated herring handling. *Wld Fishg*, **16**(3), 50–52.

ANON. 1967d Intéret de l'azote liquide pour la congélation des poissons. *Pêche marit.*, **46**(1067), 111–114.

ANON. 1967e Nouveau systéme de congélation Westinghouse pour les petits chalutiers à crevettes. *Pêche marit.*, **46**(1067), 110–111.

BANKS, A and HOUSE, C T 1958 The freezing and cold storage of mussels. *Mod. Refrig.*, **61**(724), 686–689.

BAXTER, B 1964 Trawlers fitted with accelerated fish drying tunnels. Transactions Royal Institution of Naval Architects, Madrid, September.

BREYER, F, WAGNER, R C and SELIBER, J A 1967 system for liquid nitrogen freezing of fishery products at sea. *Proc. XII Int. Congr. Refrig.*, Madrid.

DASSOW, J A 1954 Freezing Gulf of Mexico shrimp at sea. *Comml Fish. Rev.*, **16**(7), 3–9.

DIESTEL, J J 1967 Private communication.

EARLY, J C 1964 Freezing whole scampi tails. *Torry Research Report*, No. 5, 4 pp.

EDDIE, G C 1961 Freezing on board—some factors affecting design of vessels and choice of equipment. *Torry Research Report*, No. 1, 13 pp.

EDDIE, G C 1964 Some recent developments in mechanical engineering in the deep sea fishing industry. Institution of Mechanical Engineers, Grimsby.

EDDIE, G C 1967 Private communication.

ELLIS, G H and LOWCOCK, J C E 1964 Fluidised freezing. Hall-Thermotank Lecture Series.

FARBER, L 1955 Refrigeration of tuna and sardines by sodium chloride brines. *Fd Technol. Champaign*, **9**(3), 141–147.

GIANESI, G 1960 Impianti a bordo, ultimi ritrovati, costo del freddo. La congelazione rapida sulle navi da pesca. *Atti del Convegno del freddo*, Ente autonomo Fiera internazionale di Ancona, 19–34.

GIANESI, G 1963 La congelation rapide sur les chalutiers opérant dans les eaux tropicales. *Proc. XI Int. Congr. Refrig.*, Munich.

HEINSOHN, H 1967 Private communication.

LAING, A 1967 *Ibid.*

LOGAN, D 1965 The design of tuna boats. *Fishg News int.*, **4**(1), 58–64.

LONG, R A K 1955 Some thermodynamic properties of fish and their effect on the rate of freezing. *J. Sci. Fd Agric.*, **6**(10), 621–633.

LORENTZEN, G F 1963 The freezer chain—problems and possibilities. Paper presented before the Institute of Refrigeration, U.K., March, 39 pp.

LORENTZEN, G F 1964 Some problems in the nitrogen freezing of fish. *Annex 1964–4 Bull. int. Inst. Refrig.*

LORENTZEN, G F 1965 Noen forsøk me "dobbeltfrysing" av torsk. *Kulde*, **19**(4), 53–58.

MacCallum, W A and Sepic, K Commercial aspects of reprocessing and marketing of sea frozen fish. FAO Technical Conference on the Freezing and Irradiation of Fish, 4–8th September, Madrid. 1967

MacCallum, W A, Laishley, E J, Dyer, W J and Idler, D R Taste panel assessment of cod fillets after single and double freezing. *J. Fish. Res. Bd Can.*, **23**(6), 1036–1081. 1966

MacCallum, W A, Chalker, D A, Dyer, W J and Idler, D R Effects of water and dielectric thawing processes on shelf life of double frozen cod and red fish. *J. Fish. Res. Bd Can.*, **24**(1), 127–144. 1967

Meadows, V S Fluidised bed techniques in refrigeration. Trans. Institute of Refrigeration, U.K., December. 1963

Meadows, V S Fluidised freezing techniques. *Annex 1964–4 Bull. int. Inst. Refrig.* 1964

Merritt, J H Ultra-rapid freezing of fish. *Wld Fishg*, **15**(6), 39–41; **15**(7), 41. 1966

Merritt, J H Private communication. 1967

Merritt, J H and Templeton, J Freezing of fish in vertical plate freezers—effect of loading procedures. *Wld Fishg*, **12**(9), 57–62, 65. 1963

Munton, R and Stott, J R *Refrigeration at Sea*, MacLaren & Sons Ltd., London. 1967

National Association of Frozen Food Producers Code of practice and recommendations for the handling of quick-frozen foods. 1960

OECD *Fish Handling and Preservation*, OECD, Paris, 324 pp. 1965

Ogawa, Y Automatic deep-freezing on board a tuna-longliner. *Proc. XII Int. Congr. Refrig.*, Madrid. 1967

Osti, O Installation frigorifique typique des chalutiers congelateurs italiens. *Proc. XI Int. Congr. Refrig.*, Munich. 1963

Parkes, B A Harvesting the sea. *Fishg News int.*, **4**(2), 217–218. 1965

Peters, J A Time-temperature tolerance of frozen seafood. *ASHRAE Jl*, August. 1964

Peters, J A, MacCallum, W A, Dyer, W J, Idler, D R, Slavin, J W, Lane, J P, Fraser, D I and Laishley, E J Effect of stage of rigor and of freezing-thawing processes on storage quality of refrozen cod. *J. Fish. Res. Bd Can.*, **25**(2), 299–320. 1968

Ranken, M R F Some factors involved in the design of fish factory and freezing vessels for operation in tropical water. International Institute of Refrigeration Commission 8 Meeting, Cambridge, September. 1961

Ranken, M R F Some recent advances in refrigerating machinery installations in fishing vessels. *Proc. XI Int. Congr. Refrig.*, Munich. 1963

Ranken, M R F Some thoughts on the catching and processing rates to be used in the planning and design of fishing units. *In* FAO Meeting on business decisions in fishery industries, *FAO Fish. Rep.*, **22**(2), 121–136. 1964

Ranken, M R F Fish handling arrangements in stern trawlers equipped with vertical plate freezers. (MS). 1965a

Ranken M R F Les progrès de la congélation en mer. *Pêche marit.*, **44**(1047), 413–420. 1965b

Ranken, M R F The form in which fish should be frozen at sea in relation to the fishery, ship design, type and economy, and the market. *Proc. XII Int. Congr. Refrig.*, Madrid. 1967a

Ranken, M R F Quality and hot climates. *Wld Fishg*, **16**(8), 29–30; **16**(9), 42–43. 1967b

Rasmussen, C L Economics of present and future freezing methods *ASHRAE Jl*, June. 1967

Reynolds, W E and Wagner, W E Flash freezing with cryogenics, *Frontier*. 1964

Rodermund, S Gefriereinrichtungen an Bord von Fischereifahrzeugen. *Hansa*, **99**(18), 1873–1877. 1962

Slavin, J W Freezing seafood—now and in the future. *ASHRAE Jl*, May. 1964a

Slavin, J W Private communication. 1964b

Slavin, J W *Ibid.* 1967

Slavin, J W and Carlson, C J Freezing and thawing tuna at sea. *Pacif. Fisherm.* **61**(7). 1963

Slavin, J W and MacCallum, W A North American experience in catching and freezing on board vessels. *Proc. XI Int. Congr. Refrig.*, Munich. 1963

Slavin, J W and Peters, J A Freezing and storing deep-sea lobsters—some tests on cooked whole lobsters. *Comml Fish. Rev.*, **20**(7), 1–6. 1958

Slavin, J W and Smith, K A Catching and preserving New England tuna. *Fishg Gaz.*, **80**(13), 98–109. 1963

Tchigeov, G B, Vereshchagin, V A, Pukhov, V I and Tsuranov, O A Operational efficiency of tunnel and conveyor fish freezers on board vessels. *Proc. XII Int. Congr. Refrig.*, Madrid. 1967

Waterman, J J Processing lobsters. *Torry Advis. Note*, No. 6, 4 pp. 1965

White Fish Authority Freezing of fish, code of practice. London. June. 1956

Zaitsev, V P Preservation of fish products by refrigeration. Pishche promizdat, Moscow, 2nd ed., rev. and enl. (Israel program for scientific translations. IPST Cat. No. 1369, Jerusalem, 1965.) 1962

Zaitsev, V P Refrigeration engineering in the utilisation of the sea's food resources. *Fishg News int.*, **2**(4), 392–400. 1963

Freezing Fillets at Sea

by W. Flechtenmacher

Freezing fillets at sea

A brief description of the present processing practice of freezing fish fillets in large blocks aboard factory vessels of the Federal Republic of Germany is given and a forecast of possible future developments is made. The author summarizes a paper "Deep-freezing of fish fillets in blocks or in consumer packs on board factory ships", which he presented at the XIIth International Congress of Refrigeration and which describes a method of producing consumer packages of frozen fillets aboard the vessel. Such a process would eliminate any necessity of sawing large frozen blocks into consumer-size portions or thawing whole fish for reprocessing into consumer packs. Therefore, any interruption in the cold chain could be avoided.

Surgélation, en mer, des filets de poisson

L'auteur décrit brièvement la méthode employée à bord des navires-usines de la République fédérale d'Allemagne pour la surgélation des filets de poissons en blocs de grande taille, et fournit une prévision de l'évolution éventuelle. Il résume la communication ("Surgélation des filets de poisson soit en blocs soit en paquets de détail à bord des navires-usines") qu'il a présentée au XII[e] Congrès international du froid, dans laquelle est décrite une méthode permettant de préparer à bord due navire-usine un produit conditionné en unités de vente au détail. Evitant toute interruption de la chaîne du froid, le procédé élimine la nécessité de procéder au fractionnement en portions "consommateur" de gros blocs surgelés, ou de décongeler du poisson entier pour le recongeler ensuite en unités de vente au détail.

Congelación de filetes de pescado en el mar

Se describen brevemente los procedimientos de elaboración de filetes de pescado congelado en grandes bloques, a bordo de los buques-factoría de la República Federal de Alemania, y se pronostican las posibles evoluciones futuras. El autor resume el estudio que presentó al XII Congreso del Instituto Internacional del Frio titulado "La congelación de filetes de pescado en bloques, o en paquetes destinados a los consumidores, a bordo de los buques-factoría", en el que describe un método de elaboración a bordo de paquetes de filetes congelados destinados a los consumidores. Tal método eliminaría la necesidad de dividir los grandes bloques congelados en ponciones adecuadas para el consumidor o de descongelar el pescado entero para volverlo a elaborar en forma de paquetes para el consumidor. De este modo se evitarían interrupciones en la cadena del frío.

THE following is a description of the freezing of fish fillets into large blocks with contact plate freezers, and also of a new processing method for portioning fillets in consumer packs for subsequent freezing on a commercial scale. It is not intended to give a review of the whole field of freezing fillets at sea.

Processing methods of freezing blocks of fillets

On board F. R. German factory trawlers fillets are generally frozen into large blocks of 65 mm (2⅝ in) in thickness and approximately 30 kg (66 lb) in weight. Vertical plate freezers, similar to those used on British freezer trawlers, and horizontal plate freezers of the conventional type are used.

Freezing fillets in large blocks is advantageous because these can be cut into consumer packs by sawing into small rectangular portions. They are intended to be prepared for consumption (usually by frying) without being thawed. If the portioning by sawing is done at any time within the high quality life of frozen fillet blocks the product will meet the various market requirements for weight and size of consumer packs.

In the vertical plate freezing process the fillet mass is fed from a conveyor belt into vertical pockets of the defrosted freezer. The quantities necessary for each freezer pocket are weighed previously using a hand-operated weighing machine. The fillets drop from the conveyor belt through a funnel directly into waxed cartons which have been put into the freezer pockets before the filling operation. This ensures the hygienic handling of the frozen blocks after they leave the freezer.

A completely void-free frozen block is required for the later sawing into small portions. Otherwise the sawed portions will fall to pieces or will not be of the desired weight. Therefore air spaces which are formed between the irregularly lying fillets and the inner carton surfaces during the filling operation are allowed to escape before pressing the fillet mass to its block size. A device with vertical canals is introduced into each freezer pocket between the fillets and the inner carton surfaces in order to lead away the trapped air.

When the apparatus is completely filled, the vertical freezer plates, as well as one cover for each pocket, are simultaneously pressed hydraulically against the product to force it to the fixed block size. Thus rectangular fillet blocks are formed before freezing starts.

Although vertical plate freezers are used mainly, the horizontal type is necessary if blocks having a parallel arrangement of the fillets are to be produced. Such a freezing process requires handpacking and has higher labour costs than vertical plate freezing.

Freezing fillets to consumer packs at sea

Some recent installations on new F. R. German factory trawlers have adapted the conventional process of freezing fillet blocks into that of producing consumer packs by sawing the frozen blocks immediately after discharge from the vertical plate freezer. If this is to be done the fillet blocks are frozen without being wrapped and thus have direct contact with the freezer plates.

A further improvement in the processing of frozen fillet consumer packs at sea has been reported in another paper (Flechtenmacher, 1967) but its essential aspects may be of interest here.

The process of freezing fillets into ready-for-sale consumer packs on board the vessel has several advan-

tages in comparison with the process of freezing large fillet blocks. In particular temperature variations in the blocks during freezing, discharging the freezer and during any delay when the frozen product is held at elevated ambient temperature were discussed. Corresponding influences unfavourable to the product also occur in the process of freezing whole fish to blocks. To avoid losses such as waste in sawing, waste due to the portioning, and temperature losses due to the interruption of the cold chain during portioning of fillet blocks into consumer packs, the portions must be formed from the unfrozen fillets and then frozen. A single continuous processing line is used.

Measurements on board the F. R. German FRV *Walther Herwig* and in plants on board factory trawlers showed operating temperatures and condition of the equipment in contact with the product. Temperatures inside cod fillet blocks wrapped in different packaging material were measured and recorded throughout the freezing process. Defrosting of the plates before discharging the freezer at the end of the freezing cycle and the following exposure of the blocks to elevated ambient temperature on the working deck were also examined. The latter measurements showed considerable warming of the product through the interruption of the freezing chain.

Figs 1, 2, 3 and 4 show changes in the frozen product temperature during defrosting of the plates before discharging the freezer at the end of the freezing cycle and also during subsequent exposure of the blocks to elevated ambient temperature on the working deck.

Fig 1 shows typical temperature curves of a cod fillet block during delay on the working deck at elevated ambient temperature after discharging the vertical plate freezer with (B_H) and without (B_0) defrosting. The sudden temperature rise immediately after the point of time z_I in the case of defrosting is considerable. Temperatures during the freezing period are shown in part A of the curves.

Referring to B_H and B_0 in fig 1, fig 2 gives measurements of the temperature difference between the centre and 8 mm ($\frac{3}{8}$ in) below the surface of 450×400×60 mm (18×16×2$\frac{3}{8}$ in) cod fillet blocks after discharge from the freezer. This temperature difference is a measure of the effect of defrosting on the product. In all the cases examined with different packaging, it reached equal and constant values after a relatively short time. This is due to the good thermal conductivity within the frozen product as compared with the surface heat transfer. Fig 2, however, does not show the actual temperature of the fillet blocks, differently packed and discharged from the freezer in different ways.

Fig 3 shows the increase in actual temperature at the block core, up to the critical temperature range favourable for the action of enzymes, i.e. about −5°C (23°F). The time of about 3.5 h shown for a block frozen and left unpacked after discharge to warm up to −5°C (23°F) seems to be too high. This is possibly due to the lower average product temperature at the end of the freezing cycle because it was frozen unwrapped. Furthermore, since these curves represent individual examples, the values shown may only be approximate.

Fig 4 gives an analysis of the velocity of temperature changes inside the frozen product during discharging, with or without defrosting, and the following exposure to elevated ambient temperature. As it may be seen, even the temporary warming of the frozen product in defrosting has considerable effect. However, defrosting is a necessary part of the process when producing large fillet blocks or blocks of whole fish. It removes ice from the freezing plates before each freezing cycle, thus ensuring the required close contact between the plates and the product during the freezing process. It is also necessary to have the freezer plates above 0°C (32°F) during the filling operation in order to prevent voids from forming in the block through premature freezing of fillets against the carton surface in contact with the plates.

Considering that the warming of the product by defrosting is of such short duration, the question arises as to whether it is responsible for any quality loss. We know from investigations on cod by Dyer (1964) that, in

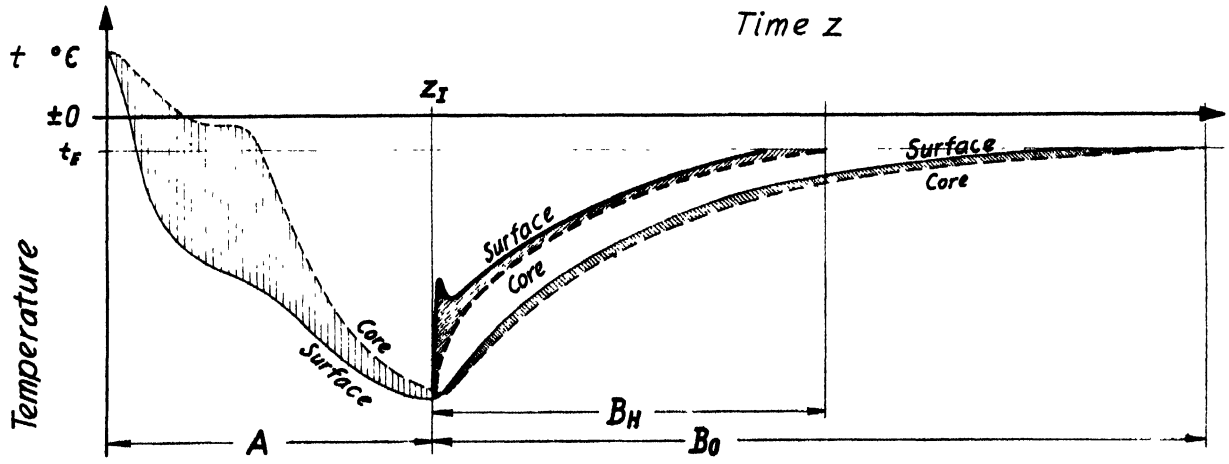


Fig 1. Typical temperature curves of a cod fillet block. A, freezing period (plate freezer); B_0, storage at room temperature of ≈ +15°C (59°F) after unloading at Z_I without defrosting; B_H, storage at room temperature of ≈ +15°C (59°F) after unloading with defrosting, beginning at Z_I; t_E, temperature range of renewed encymatic activity

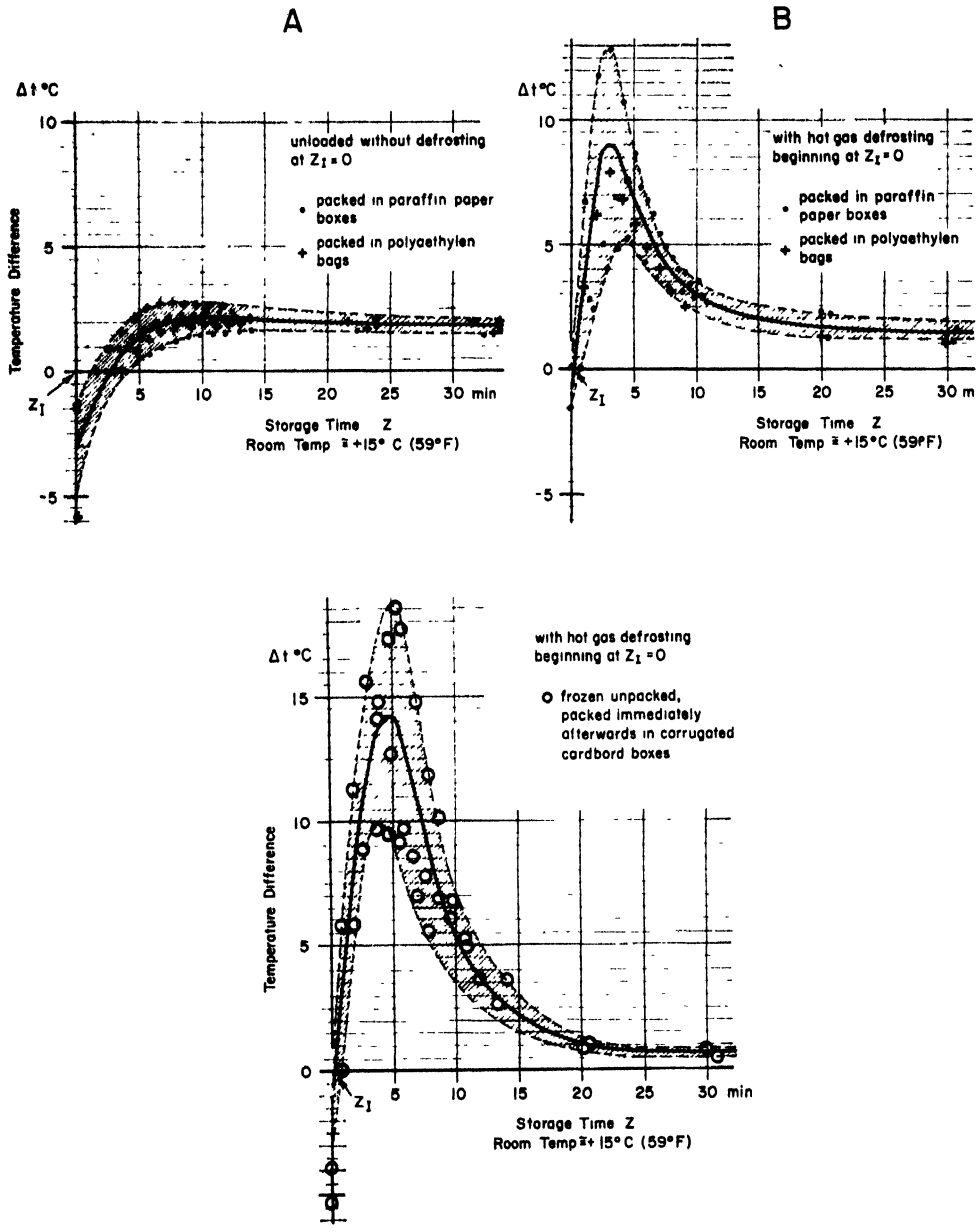


Fig 2. Temperature difference inside cod fillet blocks (60 mm; 2⅜ in) between core and 8 mm (5/16 in) below surface, immediately after unloading vertical plate freezer

cases where the product is thawed or the temperature allowed to rise for short periods, subsequent quality loss may be greater than would be expected from the time-temperature relation. Dyer found that, at least in the case of cod, an activation of enzymes or chemical reactions occur after a rise in temperature above about 15°C (59°F).

In order to prevent such possible quality loss, the product of ready-for-sale frozen consumer packs on board the factory vessels has been proposed. Such a process would be an optimum solution from the quality point of view, since it would retain the highest possible initial quality in the product.

Fig 5, (a) and (b), shows a new machine for portioning fillets into consumer packs. The automatic weighing of small consumer packs is not presently possible on board a vessel but this machine can produce packs of a fixed volume to a weight tolerance of 1 to 2 per cent. The fillets fed into a container of the machine (fig 5(a)) are forced through a funnel with a rectangular mouthpiece under a pressure of 2 to 3 atm (30 to 45 lb/in²). The pressure on the fillets is exerted from all sides, thus preventing damage to the flesh. The fillets leave the funnel as a continuous compact mass with a rectangular cross-section of, for example, 30×70 mm (1⅛×2¾ in). Different sizes and shapes of the cross-section are obtained by changing the funnel mouthpiece.

Portions are automatically cut into lengths corresponding to the required package weight, as for example into lengths of 202 mm (8 in) corresponding to a weight of 453 g (1 lb) as shown in fig 5(b). After automatic packaging, the cut portions may be fed by a conveyor

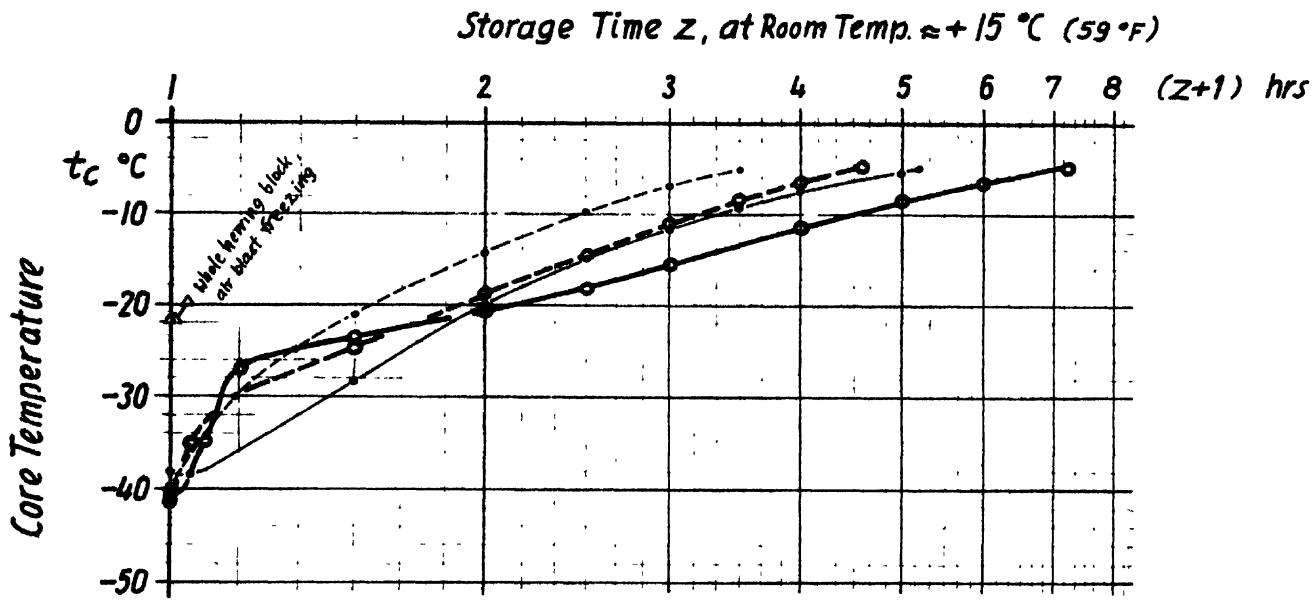


Fig 3. Core temperature in cod fillet blocks (60 mm; 2⅜ in) (after vertical plate freezing, R22-recirculation, evaporation temperature ≈ −45°C (−49°F)), – – ● – –, frozen packed in paraffin paper boxes, unloaded with hot gas defrosting; ——●——, frozen packed in paraffin paper boxes, unloaded without defrosting; – – ○ – – frozen unpacked, unloaded with hot gas defrosting, left unpacked afterwards; ——○—— frozen unpacked, unloaded with hot gas defrosting, packed immediately afterwards in corrugated cardboard boxes

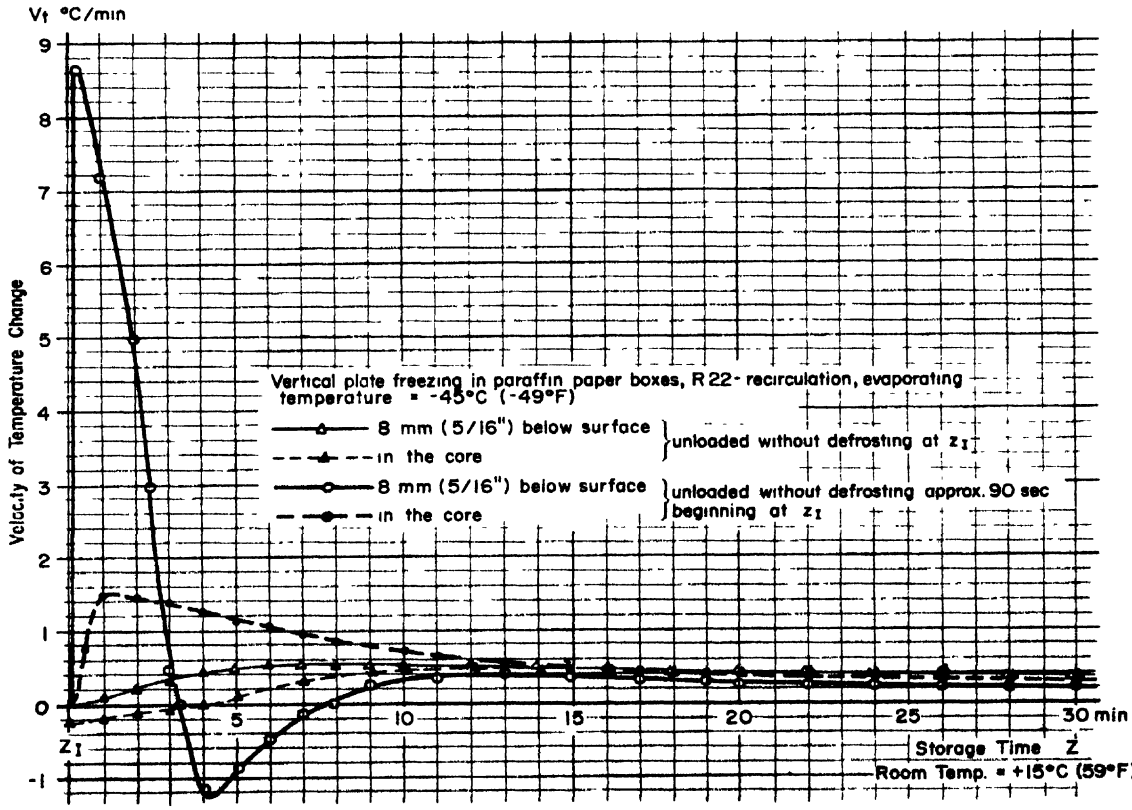


Fig 4. Velocity of temperature change in cod fillet blocks (60 mm; 2⅜ in)

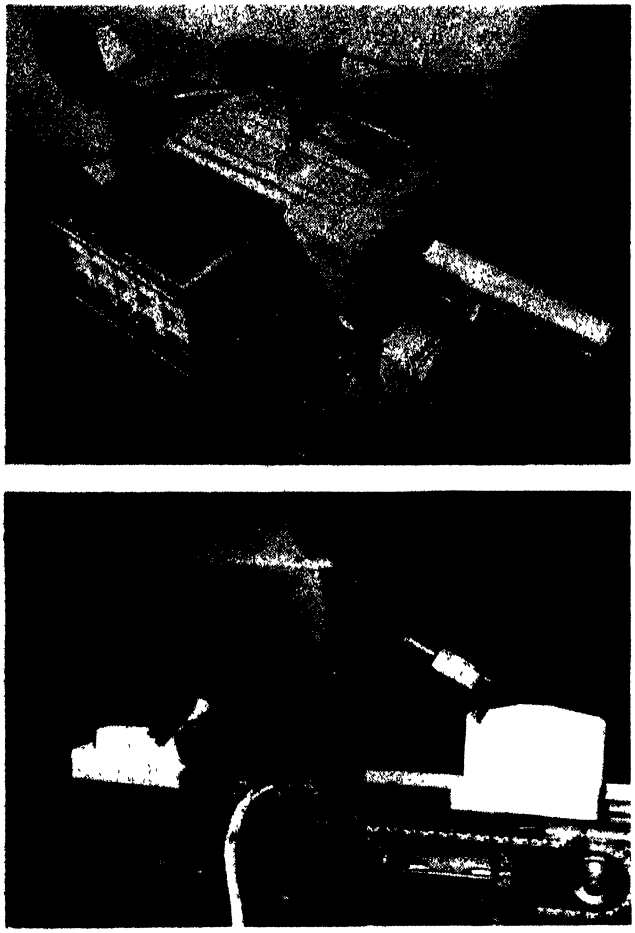


Fig 5. Fillet packing machine

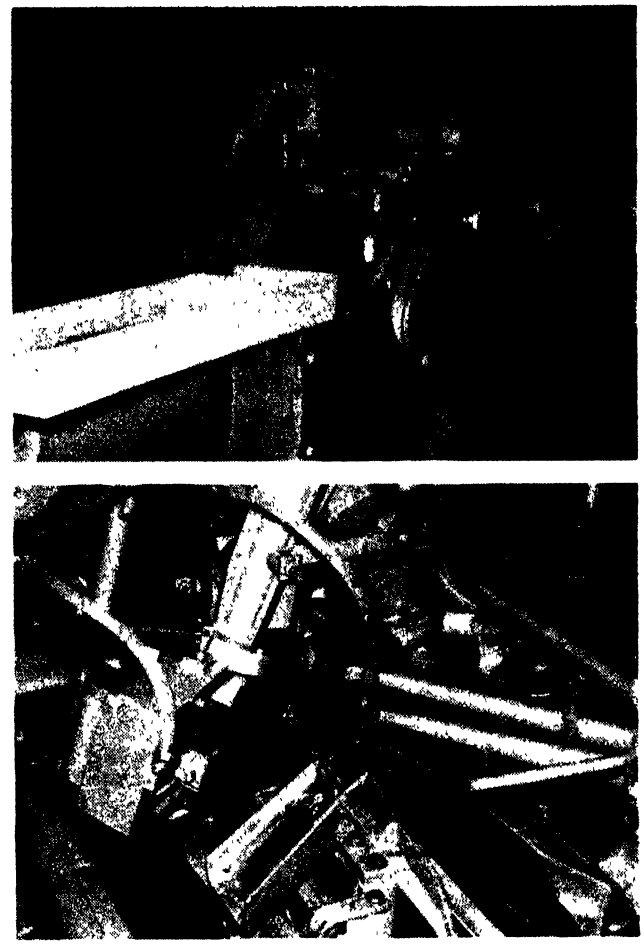


Fig 6. Filleting machine (additionally equipped with automatic device for removal of "pin" bones)

belt into a suitable automatic plate freezer. Since the fillets are packaged before entering the plate freezer, it does not need defrosting at the end of the freezing cycle. The frozen consumer packs are fed from the continuously-operating freezing apparatus directly into the refrigerated hold. Thus, there need be no interruption in the cold chain from the time of initial freezing until the product is sold to the consumer.

One person is required for the operation of the fillet-portioning machine. With a second person operating the automatic packaging machine and a third the automatic freezer, a capacity of 1-t/h of frozen 1 lb portions could be obtained.

In this production method, manual removal of the pin-bones is not possible because this would interfere with the continuity of the process. To be an optimum process for the production of boneless fillet packs, automatic removal of the pin-bones prior to portioning and freezing is required.

Fig 6, (a) and (b), shows a filleting machine of usual construction, but additionally equipped with an automatic device (fig 6(b)) for the removal of pin-bones. Two pairs of conically-arranged rotating circular knives, moving according to the shape and size of fish, cut out the pin-bones simultaneously on both sides.

Conclusion

Standardization of the size of consumer packs on the market is an essential condition for a wide application of this processing method. An international standardization of the great number of existing package sizes for frozen food would be highly desirable.

References

DYER, W J Basic quality changes in frozen sea food. *ASHRAE* 1964 *Jl*, 6, 40–42, 101.

DYER, W J and PETERS, J Factors influencing quality changes 1967 during frozen storage and distribution of frozen products. FAO Technical Conference on the Freezing and Irradiation of Fish, 4–8th September, Madrid.

FLECHTENMACHER, W Deepfreezing of fish fillets in blocks or 1967 in consumer packs on board factory ships. XIIth International Congress of Refrigeration, Commission VIII, 30th August–6th September, Madrid.

DISCUSSION

Kreuzer (FAO): It is of interest to note that in some of the newly-built freezer trawlers, provision is made for cooling the fish immediately after it comes out of the net. In the U.S.S.R., cooling tanks are now being installed on the 3,000-ton freezer trawlers of the *Mayakowski* class, into which all fish is put as it comes from the net and before it is processed and frozen. I wonder if some recommendation should be made to the industry that in the planning for construction, mechanization or improvements of freezer trawlers some provision should generally be made for cooling down the fish before freezing, especially in hot climates, as mentioned in Jones' paper (Part IB). I refer in particular to his statement that, since many textural faults, bacterial attacks and much discolouration can be eliminated at source, it is highly desirable that some facility for chilling and holding fish prior to freezing be installed on all vessels where the fish is subject to temperatures above about 10°C (50°F).

Ranken (Spain): I think Kreuzer has raised an important point to which reference is also made in Kordyl and Karnicki's paper and also that of Bose, both of which are presented in Part IID. The former paper refers to the appalling problems of handling fish in the tropics under the hot sun and stresses the need to get the fish below decks and cooled quickly. The second paper maintains the desirability of a high temperature at entry to the freezer. However, the problem is to avoid excessive damage to the quality of fish before it gets to the freezer so there has to be a compromise somewhere on those two points. Kordyl and Karnicki's paper describes very graphically the damage that is done to fish if it is not chilled quickly. I personally feel that sorting should take place after chilling and I believe this is done aboard the B23 class Polish ships where, as far as I know, they discharge the net directly into tanks and then sort the fish afterwards to discard the rubbish.

Hewitt (U.K.): In his paper, Ranken mentions the "heading" of fish when freezing them whole. This procedure has been followed less and less on U.K. vessels during recent months and now almost all fish is landed "heads on". The following reasons, to some degree or other, may have contributed to this change:

(1) Heading complicates the processing line.
(2) Heading manually is a cumbersome operation, using quite a lot of labour.
(3) Heading by machine has not been completely satisfactory because of inaccurate operation with some loss of fillet material.
(4) The heads are of some value for fish meal production.
(5) Headed fish normally have some discolouration at the cut surface. This normally has to be trimmed off on filleting, involving a loss of fillet material.
(6) The length of voyage is of the order of 50 days. Longer voyages made possible by heading the fish may introduce greater difficulties in obtaining crews.

Flechtenmacher (Germany, Fed. Rep. of): I would like to answer the question as to which kind of plate freezer is most suitable for freezing fillet blocks aboard factory vessels. Aboard F. R. German factory vessels the vertical plate freezer is used for producing blocks which are intended to be cut into consumer portions without thawing. In this case the random orientation of the fillets in the block due to the fact that they are fed into the freezer compartment through a funnel from a conveyor belt is not important. The horizontal plate freezer is used in cases where it is required that the fillets in the block be laid parallel to one another and, of course, more labour is required for this operation.

Kreuzer (FAO): There is some evidence that at least some components of the quality of fillets are adversely affected if freezing takes place during *rigor mortis*. On the other hand, the experience of the German trawlers has shown that the quality of fillet blocks is definitely satisfactory as they come from the vessel and there is evidence that the processing of fillets into large blocks where they are frozen under pressure has a good influence on the quality of the final product. Are there data available on this point? What is the German experience concerning the factors influencing the quality of fish filleted and frozen in blocks at sea? There must be some differences in the quality of the fillets as they are discharged from the vessel.

Love (U.K.): In reply to Kreuzer's question as to whether it is better to freeze whole fish or fillets, I might say that in either case we are not free from trouble, but the difficulties are not the same in each case. In the case of fillets, it is not easy to make a clean, smooth fillet on a moving ship, and any drying in the cold-store will affect the saleability of fillets more than whole fish which are filleted after thawing. However, the chief problem in fillets is one of texture. If you fillet the fish before *rigor mortis*, and it enters *rigor* and contracts before it has begun to freeze, then the texture of the product will be very tough and there will be much exudation of drip. If you fillet *in rigor mortis* and have to straighten out the fish, there is danger of tearing the muscle so that appearance suffers. Whole fish are in general easier, but not without drawbacks. We have recently been studying gaping (break-up after thawing) and found that whole fish frozen before *rigor mortis* do not gape, except at certain seasons on certain grounds for a reason imperfectly understood. If they are frozen *in rigor*, there is a big increase in gaping at all times of the year when they are well fed, though little or no gaping in starving or spent fish. As time in ice increases after death, after the resolution of *rigor mortis*, this gaping becomes steadily worse. Thus the main objection to fillet freezing is the possibility of bad texture, while whole fish may suffer from bad appearance after filleting. Much of the sale of fish depends on appearance, so this can be very important. On balance, whole fish probably are a safer bet. In neither case is there much trouble if freezing starts before *rigor* sets in, apart from discolouration, which is well known but need not make the fish unsaleable.

Rudolphi (Germany, Fed. Rep. of): For both historical and economic reasons, the dominating sea-frozen fish products in [the Federal Republic of] Germany are fillet blocks. During the experiment to obtain a self-supporting economy starting in 1936, the German consumer was subjected to an all-out government-sponsored propaganda campaign in favour of fish fillets. The government needed fishmeal, and as this commodity was scarce until 1949, the campaign was kept on. It was so successful, that even today 80 per cent of the suitable catch of the German fishing fleet is filleted. Only the confirmed fish gourmets favour round fish, and they regard frozen round fish as a second class substitute, and they don't pay a high price for a substitute. That is the situation confronting the German fish industry and trade: freezing round fish at sea does not pay in Germany. That is no theory—it has been tried for a long time. The other reason is trawler economics: the average trawler trip from German ports involves 10 non-productive days for steaming to the fishing grounds and back to port. Catching and freezing round fish means—with medium luck—10 days until the holds are filled. That is a ratio for productive to non-productive days of 1 : 1. With block frozen fillets the ratio is 4 or 5 : 1.

Little (U.K.): The question of freezing whole fish or fish fillets has been well discussed both at the FAO Conference in

Husum and the White Fish Authority Conference in London. There is little doubt in my mind that a good quality product can be produced from either whole fish or fish fillets. However, it is an indisputable fact that a lot of rubbish sometimes appears under the guise of sea-frozen fish. I do not believe that the reasons for this can be found in freezing at sea—rather we should look to the whole handling cycle—variations in temperature during landing, cold storage and retail sale must be first corrected before we look for differences in quality brought about by such sophistications as prechilling before freezing or by studying the stage of *rigor* in which the product is frozen. In my experience, under commercial conditions, all the fine differences we produce under laboratory conditions are completely negated.

Slavin (U.S.A.): I feel we are perhaps missing the point a bit. Kreuzer asked which is the best; freezing fillets at sea or freezing whole fish. The answer is: the method that results in more satisfaction to consumer. I submit that we don't have this answer, and we need to get it. One cannot look at only several variables, but must evaluate all possible efforts of total systems from catch to consumer. For example, in Part IB MacCallum covers effect of double freezing, but in reality sea-frozen fish might involve triple freezing if needed for the production of fish sticks. The technologist, therefore, must move ahead with the marketing exporter to find out what quality is satisfying to the consumer. I don't think we have the answer and we cannot continue to guess as to what the consumer likes. The further technological advances made to date have not, in my view, resulted in a higher quality product to the consumer. In commenting on Flechtenmacher's contribution on freezing fillets at sea, I would like to point out that even with his fish-forming machine there still remains the problem of using manual labour to fill the package with fish. Until a greater degree of mechanization is obtained in producing fish fillets, I would agree with Ranken that it is better, particularly in countries with highly developed fish processing industries, to keep handling at sea to a minimum by freezing whole fish. The second point I would like to make is that perhaps we have overworked freezing white fish at sea. The technology is available and we know much about quality. Problems remaining are in mechanization and in industry application. I suggest we consider doing more technological work on freezing shellfish at sea, and on freezing tropical fish.

Crépey (France): Précise que plusieurs navires français sont équipés d'installations permettant la mise en filets de poissons du genre cabillaud; les filets sont ensuite congelés dans des armoires à plaques horizontales ou des congélateurs verticaux —les quantités congelées sont de l'ordre de 20 à 40-t/jour. La production de certains bateaux est utilisée pour préparer des baguettes de poisson. Les résultats obtenus paraissent dans l'ensemble satisfaisants, on ne constate pas d'inclusions de glace trop importantes ni de poches d'air entre les filets.

Garcia Garcia (Spain): En España ya hay un barco factoria (no pesquero), el *Orense*, con dos líneas completas de fileteado mecánico con el nuevo sistema Baader, para eliminar las espinas laterales. Asimismo, están en construcción dos barcos factorías pesqueros con el mismo sistema de fileteado. Los filetes se congelan en rejillas, de peso neto homogéneo, separándolos individualmente con láminas de polietileno, en armarios congeladores de placas horizontales, tal como se enviará al mercado.

Fish as a Raw Material for Freezing: Factors Influencing the Quality of Products Frozen at Sea

by N. R. Jones

Fish as a raw material for freezing: factors influencing the quality of products frozen at sea

The quality of frozen fish products is discussed in the contexts of innate condition at catching, processing and handling prior to freezing, conditions of freezing, storage and thawing, and reprocessing.

Summarizing charts are presented relating these factors to the faults that can develop and their avoidance and cure.

It is shown that conditions prior to freezing have a critical effect on appearance and texture. Arguments are advanced for the general introduction of buffer chill storage and adequate bleeding regimes prior to freezing.

Suggestions for the upgrading of fish landed in an inferior condition are put forward. These include the use of cold stores in an unconventional manner to toughen soft material and to avoid the effects of thaw *rigor*.

Adequate labelling systems on mixed *rigor* catches are urged. The general thesis is advanced that fish technologists should aim at an intelligent versatility in approach towards an innately highly variable raw material rather than the adoption of rigid patterns of processing.

Le poisson en tant que matière première pour la congélation: facteurs affectant la qualité des produits congelés en mer

La communication traite de la qualité des produits congelés à base de poisson en examinant l'état lors de la capture, le traitement et la manipulation précédant la congélation, les conditions dans lesquelles s'effectuent la congélation, l'entreposage et la décongélation, enfin, la transformation ultérieure.

Des diagrammes récapitulatifs établissent un rapport entre ces divers éléments et les défauts qui peuvent apparaître, indiquant les moyens de les éviter on d'y remédier.

L'auteur fait ressortir que le traitement du produit avant la congélation a un effet décisif sur l'aspect et la texture. Il préconise l'adoption généralisée, avant la congélation, de l'entreposage "intermédiaire" sous réfrigération et d'une saignée adéquate.

La communication présente des suggestions permettan d'améliorer la qualité du poisson mis à terre en mauvais état, par exemple l'utilisation, en dehors des formules classiques, des entrepôts frigorifiques pour durcir les tissus ramollis et éviter les conséquences de l'apparition de la *rigor mortis* à la décongélation.

L'auteur préconise l'emploi de systèmes de "marquage" pour identifier à quel stade se trouvent les divers poissons d'un lot par rapport à l'apparition de la *rigor mortis*. Sa thèse générale est que les technologues halieutiques doivent, étant donné les grandes variations naturelles que présente la matière première, s'efforcer de faire preuve de souplesse plutôt que d'adopter des schémas rigides de transformation.

El pescado como materia prima de la congelación; factores que influyen en la calidad de los productos congelados en el mar

Se examina la calidad del pescado congelado en el contexto de las condiciones existentes al realizar las capturas, al elaborarlo y manipularlo antes de la congelación, las condiciones de la congelación, almacenamiento y descongelación y la reelaboración.

Se presentan gráficas resumidas que relacionan estos factores con los defectos que pueden surgir y el modo de evitarlos y remediarlos.

Se muestra que las condiciones existentes antes de la congelación poseen un efecto crítico sobre la apariencia y la textura. Se ofrecen argumentos en favor de la introducción general del almacenamiento refrigerado compensador y adecuados regímenes de sangría antes de la congelación.

Se hacen indicaciones para mejorar la calidad del pescado desembarcado en inferiores condiciones. Entre ellas figura el empleo en forma especial de cámaras frigoríficas para endurecer el material de textura blanda y evitar los efectos de la rigidez cadavérica en la descongelación.

Se pide que se establezcan adecuados sistemas de etiquetado en las capturas en distintas fases del *rigor mortis*. Se adelanta la tesis general de que los tecnólogos del pescado, en lugar de adoptar un tipo rígido de elaboración, deben estudiar diversas formas de ésta pues se trata de una materia prima ya de por sí altamente variable.

THE commercial development of freezing at sea has been an object lesson in the difficulties of extrapolating laboratory and pilot exercises to large scale, practical operations on freezer trawlers with all their attendant pressures of time, crewing and economics. We now see that while considerations of toughening in cold store and of oxidation problems, which occupied much research effort from the early 1930s onwards are of relevance, other factors, relatively unexplored, can be of greater importance in situations where storage periods are short and the fish passes rapidly to the consumer.

Furthermore, we find that technical difficulties tend to appear sporadically in the industry: a pattern of operation can produce satisfactory material over a period of months and then products from a catch or catches can become suddenly altogether unacceptable. At the same time, a consideration of the research literature in relevant fields (particularly of the outputs of groups publishing on the basis of experimentation of small numbers) shows that findings are frequently contradictory. It can be deduced, therefore, that, in fish, we are dealing with innately very variable raw material.

As technologists we have to explore the economic possibilities of minimizing the incidence of unacceptable produce. In practice, this involves some understanding of the bases of quality, of the causes of variability and change, and of their avoidance and control. These cannot be discussed in any depth in a paper of this length, but the author hopes to present a broad background, with referencing intended to lead on to the detailed literature.

At the London Conference on the Design of Fishing Vessels and their Equipment in relation to the Improvement of Quality (in 1965) there was some discussion as

to the relevance of such considerations to the industry and those of us who have an interest in quality matters in the context of freezing at sea had some cause for satisfaction. Clear evidence from the marketing side (e.g. Sale, 1965) indicated that quality in frozen fish pays. In the following sections the different attributes of quality (as understood both by the consumer and by the processor, who has additional criteria) will be related to (a) innate condition as the fish comes to the deck, (b) handling and processing prior to freezing, (c) freezing, (d) storage, (e) thawing, (f) reprocessing, (g) refreezing and (h) cooking. Some of the factors relating to fillet freezing have been discussed in greater detail in an earlier paper (Jones, 1965c) which summarizes the general literature on prefreezing aspects up to that point.

The various factors, from innate condition at the point of catching to processing, that affect quality, are related to each other in a complex manner. Some of the variables from the point of catching onwards are indicated in fig 1. Their effects will often be determined in practice by considerations imposed by the economics of ship-board processing (particularly in terms of space, man-power and equipment).

QUALITY IN FISH PRODUCTS

General

A rational study of freezing at sea and of the subsequent progress of the product to the consumer does not lend itself to over-simplification. In this discussion, quality is taken to be the key but the extent to which the arguments developed can be implemented must, of course, depend on the economic balance that applies under any particular set of circumstances. Flavour, odour, texture and appearance are important to varying degrees and in perhaps differing senses according to the points of purchase. The housewife, for instance, will tend to be interested in the traditional criteria for quality in wet fish if she is presented with thawed, filleted material. Consequently, she will look for a white, translucent, glossy fillet of good odour. She may be seriously in error, however, if she equates the discolouration which results from poor bleeding prior to freezing to the reddening that would indicate terminal bacterial attack on the major blood vessels of chill-stored fish. On the other hand, a consumer presented with cooked fish of these origins would readily distinguish between them on the grounds of flavour, whereas appearance would be largely irrelevant. In so far as the housewife has not learned to appreciate the significance of differences in appearance between chilled and frozen fish to date, the processor must concern himself with such factors in determining his pattern of processing and marketing. He is interested also in other qualities, such as yield at reprocessing and ease of fabrication for such products as fish sticks.

Flavour

The flavour chemistry of fish has been reviewed recently (Jones, 1965b). Within a species, flavour can vary from ground to ground and season to season according to the nature of the food and physiological conditions. Innate flavour varies, of course, considerably from species to species. Furthermore, patterns of flavour change that develop *post-mortem* are also species-dependent. Some, such as plaice (*Pleuronectes platessa*), are commonly considered to improve in flavour a little immediately *post-mortem*, before autolytic and microbiological deteriorative changes set in, whereas such effects are not commonly noted in many other white fish species such as cod (*Gadus callarias*). There are very great differences between the spoilage patterns of fatty species of fish, in which oxidative deterioration is usually accelerated by the presence of haem pigment, and non-fatty species, in which one can more clearly distinguish phases of spoilage resulting sequentially from the activities of tissue enzymes and a developing spoilage micro-flora.

Flavour deteriorations *post-mortem*, other than those due to oxidation reactions (Olcott, 1962), have not commonly been considered as subjects relevant to freezing technology in so far as freezing has the object of suppressing such activities. However, autolysis and bacterial spoilage can be encountered in sea-frozen material, particularly under tropical conditions where the fish is not chilled when it comes to deck, and there is evidence that both tissue and bacterial enzymes can continue to be active in the frozen state. Shewan (1962) and Jones (1962) have reviewed microbial and autolytic spoilage in general terms. Ranken (1961, 1965) has discussed the advantages and practice of chilling prior to freezing in terms of such deterioration in vessels operating in tropical waters.

Of the different factors producing flavour change in cold-stored fish, oxidation of fats and carbonyl-amino reactions are of considerable importance in species such as herring (*Clupea harengus*). The products of the reaction are in themselves undesirable and, together with sugars and sugar phosphates, react with amino constituents to form other compounds that confer off flavours. There is evidence that in some species, the breakdown of mono-nucleotides (which confer desirable meaty character and mask certain undesirable flavours) can proceed in the frozen state and also during freezing and thawing (Jones, 1963). It is believed that the loss of flavour commonly reported to be a consequence of freezing and thawing derives in part from such reactions and that the appearance of bitterness is related to the liberation of hypoxanthine in the muscle.

Texture

In the context of eating texture we are concerned with such factors as "shortness", "stringiness", "rubberiness", "mushiness" and various other attributes which we may, perhaps, group broadly under the heading of degree of toughness. What might be termed processing texture is related primarily to ease of filleting and handling and it is associated with the appearance of the fish also. "Break-up" in fillets, for instance, is associated with poor filleting characteristics.

The water-binding capacity of the muscle proteins controls both processing and eating textures. It is affected by at least two factors (probably more). Muscle pH is an important factor in the texture of sea-frozen material (Kelly *et al.*, 1966). pH is dependent upon the conditions

of glycolysis, *pre-* and *post-mortem* and hence is in itself highly species-dependent and subject to environmental factors. Although the balance of evidence in this field is clear, it still appears to be a matter for controversy (Tarr, 1966). Fish of good nutritional status, killed with a minimum of struggle, tend to accumulate more lactate *post-mortem* than starved exhausted fish. Lactate accumulation correlates with low water-binding capacity in muscle and with toughness (Jones, 1965a). High "drip" loss from muscle is associated with low pH.

Another cause of low water-binding capacity is myosin aggregation reaction at sub-zero temperatures ("cold storage denaturation"). Again, this is a somewhat controversial subject in itself (Connell, 1962; Anderson *et al.*, 1963; Hanson and Olley, 1965). It has, for instance, been suggested that lipolysis liberates catalysing free fatty acid that catalyses aggregation in frozen tissue—and alternatively that this free fatty acid effect, observable in the laboratory, is an artifact. Recently it has been demonstrated that the "cell fragility" method, which monitors cold storage denaturation, responds in a directly contrary sense to pH-dependent toughness (Kelly *et al.*, 1966).

Eating texture can also relate to *rigor* shrinkage in muscle (Jones, 1965a) in a manner that is apparently similar to that recently reported in mammalian muscle, although such shrinkage/toughness relationships are not observable invariably (Little, personal communication). Certainly, processing texture relates very closely to such *rigor* contractions. Of particular significance to freezing at sea are the markedly different effects of allowing *rigor* to develop with the muscle attached to the bone (as may be the case if the freezing of whole fish is delayed) as compared with that when excised muscle is allowed to enter *rigor* at high temperature unattached. In the former case, the connective structures between muscle blocks can break under the tensions developed within blocks so that the material becomes unfilletable. This effect is to be noticed particularly in some species adapted biochemically to life at low temperature when conditions of catching, holding and processing subject them to high temperatures either in surface waters or on deck. Such damage is common in *Merlucius* species. In cod (*Gadus callarias*) there is a critical temperature (17°C, 62°F) above which the causative biochemical reactions are greatly accelerated. In general, tropical surface-living species are adapted to life at very much higher temperatures. They do not appear to be generally so susceptible to breakdown effects, but this is a little-explored field. It may be noted, however, that the "honeycombing" of canned tuna can be minimized by refrigeration from the point of catching, prior to freezing for transport to the cannery.

Conditions of thawing can also control eating texture and suitability for reprocessing. In fish stick production, considerations of water-binding capacity and contraction can be critical factors determining suitability for processing. Under the conditions of rapid thawing that can occur during cooking from the frozen state, muscle that retains its innate contractility can buckle and shrink. Together with low pH, this results in a mis-shapen product, poorly battered and altogether unsatisfactory. By contrast, conventionally-iced wet fish, which has lost its contractility and in which the pH has risen under the activities of the developing microflora, produces an excellent product, provided that bacterial attack has not proceeded to a stage where adhesion between the muscle blocks breaks down. There are suggestions in the literature that, for practical purposes, thaw *rigor* can be ignored as a factor in the processing of *pre-rigor* frozen fish (e.g. Partmann and Gutschmidt, 1963). From reasons of innate variability in fish muscle and from practical observation, the author believes this to be an overgeneralization, particularly under conditions of "cook-thawing" or under some of the more rapid industrial conditions of thawing such as are indicated in fig 1. Thaw *rigor* can be readily demonstrated in single frozen,

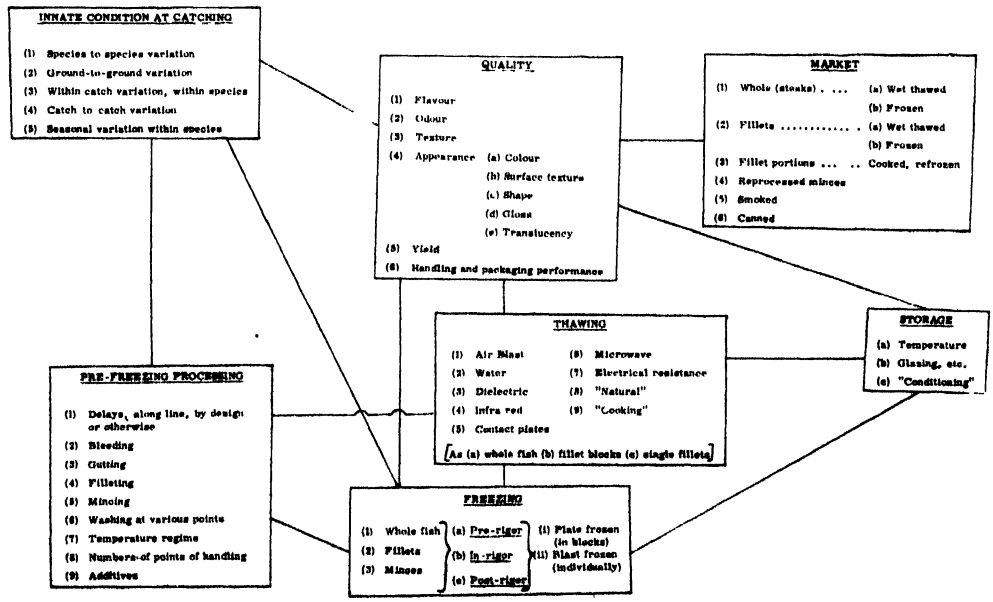


Fig 1. Variables in frozen fish production and processing

pre-rigor fillets subjected to warm air thawing (McDonald and Jones, 1967). Such conditions can be controlled, however, by allowing relevant biochemical reactions to proceed at sub-zero temperatures in a pre-thawing conditioning store.

As has been briefly indicated above, some "gaping" or "break-up" of fillets can result from over-extended periods of stowage prior to freezing and this is particularly the case if temperatures are high, even though no high-temperature *rigor* phenomena may be observable. Another cause of break-up is rough handling of fish in a stiffened condition, whether the stiffening derives from *rigor* itself or from freezing. Such ill-treatment of fish in *rigor* can occur, for instance under the conditions of transference at sea from a catcher to a freezer vessel.

Appearance

In so far as fish is still sold wet in many countries, on appearance rather than on nutritional value or flavour or texture, the fish technologist must concern himself presently with factors that may prove to be irrelevant in the longer term, as more of his product is either cooked in the home from the frozen state or is processed and factory-cooked prior to sale refrozen. The major consumer resistance to sea-frozen fish in Europe has undoubtedly been on its appearance.

Opacity in sea-frozen fish can result from denaturation reactions (see above) during freezing, storage and thawing. In fillets, as distinct from whole fish, an additional "grey" opacity results from a light-scattering effect at the surface, which, on microscopic examination, presents an appearance similar to sandpaper (Jones, 1964a). This is an effect of cutting across *pre-rigor* fibres and not observable in other material.

In addition to greyness, fish frozen at sea is frequently found, at thawing, to be badly discoloured by blood pigments and their break-down products. Conditions of freezing are commonly such that blood, that would be lost from conventionally-iced material into the leaching ice-melt water, is retained in the flesh. Other conditions of prior handling being similar, whole-frozen fish proves on thawing to be markedly superior in this respect to fillets. This is particularly the case with *pre-rigor* frozen material. The pigment cannot be removed by washing. Considerations of the factors controlling blood-clotting times, capillary contraction *post-mortem* and the contractility of the tissue as a whole promise to lead to an eventual rationalization of bleeding technique. Presently, empirical experimentation indicates that very considerable advantage derives from lowering the temperature of the fish as rapidly as possible after hauling, together with rapid bleeding by throat-cutting or gutting (Jones, 1965c).

A yellowing or browning resulting from carbonyl-amino reaction is also frequently observable. Such reactions are temperature-dependent and hence controllable by low storage temperature. Experimentally the author has had limited success in controlling such reactions with sulphite, but this is less effective than for dehydrated material.

Some species are prone to enzymic discolouration either prior to freezing or subsequently. This is of polyphenol oxidase type and is commonly found in shellfish. A measure of control is often obtainable by the avoidance of blood spotting at slaughter. Attempts at control by sequestering polyphenolic or potentially polyphenolic material and/or catalysing of ions have not been particularly successful in the author's experience. Considerable practical advantage in shellfish freezing can derive, however, from a preliminary leaching *post-rigor* to remove the substrate. This advantage is gained at the expense of some loss of flavour.

SOME PRACTICAL CONSIDERATIONS IN CATCHING AND PROCESSING

The ground

As we have seen in the preceding sections, ground can affect critically all the major aspects of quality. The avoidance of certain grounds at certain seasons can eliminate many problems. However, in a situation where catching rates are decreasing overall, the advantages of quantity processing will often outweigh incidental technical difficulties economically. Future contributions of the scientist and fish technologist to the industry could profitably concentrate on the developments of satisfactory upgrading processes and the utilization of species currently avoided for technological reasons.

Basic pattern of freezing and thawing

Individual vessels can freeze fillets, whole fish, minces or all three. The economic conditions within the processing and distributing sections of the industry, together with crewing and running cost of vessels, vary widely from country to country and present a picture of continual change within countries. Consequently, the author will not consider the relative merits and demerits of the different patterns of processing in detail. Apparent advantages in terms of the higher storage rate for fillets and the avoidance of offal freezing may well be counterweighed in practice by the high demands on space and labour implicit in fillet freezing. Additionally, certain (avoidable) technical difficulties can arise in fillet processing: but these have a counterpart (presenting different symptoms) in whole fish freezing.

The 1965 London Conference did not resolve a contradiction between the claims of the filleting machine manufacturers and observations of certain disinterested senior research technologists on the performance of machines on *pre-rigor* and *in-rigor* fish. Undoubtedly there is a certain incidence of tearing.

Pre-rigor frozen fillets present greater problems with discolouration than whole fish. They often present a better appearance than whole-frozen material in other respects, although they are subject to shrinkage. This is not necessarily taken to be a fault in some countries (e.g. Norway). Conversely the grossly broken appearance sometimes presented at the filleting of whole-frozen fish can be a severe restriction on possible marketing outlets.

A number of vessels are equipped for freezing a variety of material. For instance, the air-blast freezers on certain Japanese freezer-trawlers are designed to take whole fish,

fillets and minces. Whatever the pattern of processing, the operation of the vessel from the time that the catch comes to the deck falls into two distinct phases: firstly, killing and any incidental processing; secondly, freezing. For present purposes we may consider that conditions of subsequent cold storage will be satisfactory.

Considering firstly whole-fish freezing. The fish may be frozen *pre-*, *in-* or *post-rigor*. This will determine the quality of the material at thawing and there is a very good case for the marking of blocks by some characteristic code to indicate the *rigor* condition at the point of freezing. Under present working conditions on many freezer-trawlers it is impracticable to demand consistency in quality within a catch as the fish must be handled as rapidly as possible under conditions which may not approximate to the ideal. *Pre-rigor* frozen fish may be susceptible to thaw *rigor*. They are also frequently discoloured. *In-rigor* frozen fish can present a broken appearance if handled roughly. Broken fillets are more often, however, the result of passage into and through *rigor* at high temperatures or that of undue delay in freezing *post-rigor*. All of this fish may be usable, along different patterns of processing. Under present conditions, where patches of heavy fishing may be infrequent, it is highly desirable to make maximum use of the material. For instance, polyphosphate/brine dips can be of value in improving the appearance of broken fillets packed in interleaved blocks for refreezing.

Since many textural faults, bacterial attack and much discolouration can be eliminated at source, it is highly desirable that some facility for chilling and holding fish prior to freezing be installed in all vessels where fish are subject to temperatures above approximately 10°C (50°F). However, such chilling carries a penalty in terms of "non-productive" space requirement (as some operators would consider it). In the past, many catchers have preferred to accept a varying incidence of very poor quality landings.

With regard to quality in sea-frozen fillets, we are again concerned with the *rigor* conditions. This is of importance prior to filleting, at filleting and at freezing. Space does not allow a detailed consideration of all the factors involved either in this operation or in whole-fish freezing in this context, but they have been reviewed (Jones, 1965c). *Pre-rigor* cut fillets are subject to contraction (both prior to freezing and at thawing) and to a rather poor surface appearance. They tend to discolouration, and lack gloss and translucency. Chill temperatures and careful gutting/bleeding procedure prior to freezing together with careful thawing can produce an excellent fillet, however. *In-rigor* or *post-rigor* filleted material presents relatively little difficulty if the precautions indicated for whole fish are followed.

In both classes of freezing, bleeding and/or gutting procedures are closely related to temperature control in the avoidance of textural, flavour and discolouration problems. Notwithstanding the observation made above concerning "non-productive" space, neither of these requirements appear to be at variance with current engineering thought, although they have been considered impracticable by some commercial operators (Sealey, 1965). Indeed, the Polish B23 trawlers, vessels such as the East German *Tropik* and certain South African and British freezer trawlers operate chilling facilities, whereas the Icelandic freezer trawler *Narfi* conducts both bleeding and gutting operations. The author does not suggest that bleeding need necessarily be separated from gutting: frozen fillets of good colour can be obtained by gutting alone if this is carried out soon enough under chill conditions.

The freezing of minced fish has certain attractions as a source of material for reprocessing. It is not always suitable for fish stick production since the processor ashore may offer a premium for recognizable muscular structure in the block. Fish in this form is entirely suitable for fish sausage production, however, and in Japan it is used for the production of kamaboko. Freezing fish as a mince can enable the shipboard processor to incorporate additives such as polyphosphate or glucose in the block to improve yield at thawing and the quality of the product at reprocessing ashore (Akiba *et al.*, 1967).

It will be appreciated that considerations of pre-freezing processing, of freezing, of thawing and of reprocessing should not be considered separately. Neither should engineering considerations be taken separately from those of general quality. As the author understands the development of the programme of the Conference, however, such a separation is to be made between the subject matters of sessions in this meeting and he will restrict observations of plate freezing and blast freezing to noting that blast freezing affords a greater measure of versatility in size, shapes of pack, etc., than plate freezing as he has seen it in practice. However, as Ranken (1965) has pointed out, blast freezing operations at sea are more space consuming, more labour consuming and more vulnerable to poor design or operation so that the quality standards achieved are seldom comparable to those achieved with plates.

Such poor design frequently shows up as "freezer burn" (freeze drying as a result of handling at too high a temperature in the freezer). There must be many attending this meeting, however, who have also seen samples of plate-frozen material showing such faults and also the effects of transference to cold store with the interior of the fish still unfrozen.

In holds and stores, stowage rates as blocks are higher than those of separate fish or individually frozen fillets. Nevertheless, some owners have been considering possibilities of single-fillet freezing for marketing in that form without further reprocessing. Such products are more prone to "freezer burn" and drying out during storage. They have to be protected from desiccation more rigorously than by glazing with water which is quite acceptable for whole blocks. It is to be hoped that the session will include a separate consideration of packaging.

Detailed discussions of thawing techniques are to be presented elsewhere in this meeting. The freezing of small packages of fish or single fillets *pre-rigor* can present difficulties at thawing. As indicated above, thaw *rigor* can be a problem in such material at cooking. Similarly, it can occur in portions of *pre-rigor* blocks sawed for fish stick production. While it is commonly thought that thaw *rigor* is not important in *pre-rigor* whole fish we have seen above that it can be a sporadic factor in marketability. In the context of the development of commercial rapid

thawers it would appear to be well worth while taking steps to identify potentially troublesome material by labelling blocks at sea for preliminary routine quality control examination ashore.

McDonald and Jones (1967) have shown that suitable pre-conditioning can eliminate a tendency to thaw *rigor* in single-frozen fillets destined for warm air thawing. Conditioning in these terms means subjection to a period of relatively high temperature storage prior to thawing. It is appreciated that such storage leads to deteriorative reactions affecting stabilities of proteins and flavour. On balance, however, some frozen fish clearly improve overall from a period of "poor" storage. Not only is this true of the proportion of *pre-rigor* frozen material that may be susceptible to thaw *rigor*: it can also benefit some very soft-textured *post-rigor* material such as *Merlucius* species. Here, however, there is a very delicate balance between a desirable toughening of material and the onset of fat oxidation with its attendant off-flavours.

CONCLUSION

Currently the pattern of marketing varies widely from country to country. In the United Kingdom, a considerable proportion of the fish sold passes to the consumer at the point of sale in the wet form. Much of this is conventionally-iced material and in practice it has been found that sea-frozen fish (whether whole-frozen or fillet-frozen) is not competitive in the thawed state on grounds of appearance as discussed above. Many of these rather superficial objections to sea-frozen fish can readily be overcome by a modification of processing methods, prior to freezing, particularly in terms of bleeding and chilling. However, it is apparent that, with the growth of "convenience foods", more frozen fish will pass to the consumer in a form ready for cooking or simply re-heating. As such, it will reach him as single fillets or portions. Superficial appearance, as it would have concerned him in the wet form, will no longer be relevant. The processor, however, will still be concerned with considerations of yield and ease of handling and of reprocessing.

In part, these factors can be controlled at source, prior to freezing. However, the enlightened processor and quality controller ashore can together do much to surmount difficulties in the utilization of low-grade material. The use of polyphosphate, for instance, as a pH modifier and simulator of the original adenosine 5-triphosphate of the muscle is now well established although controversial. It can confer desirable characteristics in terms of increased water binding capacity with attendant benefits in yield and eating texture. It can also partially confer (particularly in combination with brining and a little firming up in cold store) desirable fillet texture and appearance to badly-broken material. Poor flavour can be improved by the use of appropriate additives: e.g. mononucleotides and mono-sodium glutamate.

Tables 1, 2 and 3 summarize faults that can occur in frozen fish and steps towards their avoidance and cure. It will be appreciated that variability in the fish as it reaches the deck is such as to preclude rigid patterns of operation. The requirement in modern fishing and processing is for men aware of the wider background to the operation, with the biochemical and engineering knowledge to manipulate inherently fluid situations.

TABLE 1. COMMON QUALITY DEFECTS OF FLAVOUR AND ODOUR IN FROZEN FISH AND THEIR CONTROL

Fault	*Possible causes*	*Avoidance*	*Further control procedure*
(A) Atypical flavour for species	(A) Ground	(A) (1) Change ground	(A) (1) Leach flesh to remove off flavour (2) Mask flavour with mono-sodium glutamate/ nucleotides
(B) Burning after taste. Rancidity (oxidative, hydrolytic)	(B) (1) Poor cold storage conditions	(B) (1) Lower temperatures, antioxidant? glazing/packing?	
	(2) Inefficient bleeding (haem catalysis of oxidation)	(2) Improved bleeding technique (rapid gutting, chilling)	
	(3) Partial deterioration prior to freezing	(3) More rapid operation, chilling	
(C) Loss of sweet, meaty, characteristic flavour. Increase in bitterness	(C) (1) Autolytic deterioration prior to freezing	(C) (1) More rapid operation, chilling	(C) (1–4) Monosodium glutamate/nucleotide additives
	(2) Autolytic deterioration at freezing	(2) More rapid freezing	
	(3) Autolytic deterioration in store	(3) Lower temperature	
	(4) Autolytic deterioration at thawing and subsequently	(4) Rapid cooking from frozen state	
(D) Amine-like or ammoniacal off flavour	(D) (1) Spontaneous degradation of trimethylamine oxide and adenine nucleotides in cold store	(D) (1) Lower temperature in store	(D) (1, 2, 3) Leach prior to cooking. Masking with monosodium glutamate/ nucleotide additives
	(2) Bacterial attack prior to freezing	(2) More rapid operation prior to freezing. Chilling	
	(3) Attack by bacterial enzymes (formed prior to freezing) in store	(3) Lower cold storage temperature	
(E) "Sulphydryl", lower fatty acid, putrid flavours	(E) (1) Bacterial attack prior to freezing	(E) (1) Lower temperature, etc. (As (D)(2) and (3))	(E) (1) As (D)

TABLE 2. COMMON QUALITY DEFECTS OF TEXTURE, DRIP AND YIELD IN FROZEN FISH AND THEIR CONTROL

Fault	*Possible causes*	*Avoidance*	*Further control procedure*
(A) "Toughness", "drip" loss	(A) (1) High acidity	(A) (1)	
	(a) associated with nutritional status (ground, season)	(a) Change ground } Raise pH with polyphosphate	
	(b) associated with fishing method	(b) Change method } Raise pH with polyphosphate	
	(c) associated with processing regime prior to freezing	(a) (b) (c) Allow maximum struggling if fish comes to deck alive (c) Allows incipient spoilage to raise pH if flavour not a prime consideration	
	(2) Protein aggregation reactions (particularly if accompanied by poor surface gloss and "grey" appearance)	(2) Lower cold storage temperatures	(2) Polyphosphate and/or brine dips
	(3) High temperature *rigor* effects	(3) Chilling prior to freezing	(3) Polyphosphate/brine treatment of fillets
	(a) on the bone (accompanied by break-up at filleting either before or after freezing)		
	(b) off the bone (accompanied by shrinkage)		
(B) Soft, "mushy" at eating	(B) (1) Low acidity	(B) (1)	(B) (1)
	(a) associated with nutritional status (ground, season)	(a) Change ground	(a) (i) Acidification? (ii) Allow some cold storage denaturation
	(b) delay in handling, particularly extended periods at high temperatures, ungutted	(b) Gut quickly: freeze with minimum delay; chill	
(C) "Short" and granular texture	(C) (1) Cooking *pre-rigor* material	(C) (1) (a) Allow to enter *rigor* prior to freezing (b) "Condition" to allow causative reactions to proceed in the frozen state (c) Thaw slowly: cook from thawed condition	
(D) Low yield	(D) (1) Drip loss associated with contraction, protein denaturation, etc. (see above)	(D) (1) See above	

TABLE 3. COMMON QUALITY DEFECTS OF APPEARANCE IN FROZEN FISH AND THEIR CONTROL

Fault	*Possible causes*	*Avoidance*	*Further control procedure*
(A) "Grey" colour in fillet accompanied by opacity and drip. Lack of gloss but smooth surface	(A) (1) Protein aggregation reaction in cold store	(A) (1) Lower cold storage temperature	(A) (1) Polyphosphate/brine
(B) Opacity associated with a light-scattering effect from a surface of sandpaper-like consistency	(B) (1) *Pre-rigor* frozen fillet	(B) (1) Delay filleting	(B) (1) Re-cut fillet at thawing
(C) Badly broken or gaping fillet	(C) (1) Rough handling when the fish is in *rigor* (e.g. by manipulation on deck or during transference between vessels)	(C) (1) Careful handling	(C) (1) Broken fillets dipped in polyphosphate/brine. Compressed in interleaved blocks prior to freezing
	(2) High temperature *rigor* effects when muscle attached to skeleton	(2) Chill immediately on catching and prior to freezing	(2) As (1) if protein not irreversibly damaged
	(3) Bending, knocking in frozen condition	(3) Careful handling	
	(4) Excessive delay in freezing, particularly of ungutted whole fish		(4) As (1)
(D) Shrunken, distorted fillet	(D) (1) *Pre-rigor* cut: contraction prior to freezing when flesh not attached to skeleton	(D) (1) Speed pre-freezing operations, avoid rough handling, chill	
	(2) Thaw *rigor*	(2) (a) "Condition" prior to thawing by a period of relatively high temperature treatment in cold store	
		(b) Thaw slowly	
(E) Distorted fish sticks	(E) (1) Sticks cut from block frozen *pre-rigor*	(E) (1) (a) Substitute *in-/post-rigor* frozen blocks	
		(b) "Condition" *pre-rigor* frozen blocks prior to sawing	
(F) Red/brown discolouration at surface			
(1) Generalized, or subdermal reaction	(1) Carbonyl-amino reaction	(1) (a) Lower store temperature (b) Glaze	(1) Antioxidants/sulphite as permitted by regulations
(2) Generalized, but frequently more pronounced at surface	(2) Haem pigment contamination, possibly together with (1) (condition worse in *pre-rigor* frozen fillets than whole-frozen material treated similarly)	(2) (a) Adequate bleeding. Fish cut and chilled immediately it comes to deck, preferably in contact with sea water	
		(b) Delay filleting until *rigor* well advanced	
(3) Discoloured belly flaps	(3) Gut breakdown	(3) Early evisceration	
(4) Discoloured desiccated surfaces	(4) "Freezer burn"	(4) Low freezer and storage temperatures	(4) Glazes, suitable packaging

References

AKIBA, M, MOTOHIRO, T and TANIKAWA, E *J. Fd Technol.*, 1967 **2**(1), 69.

ANDERSON, M L, KING, F J and STEINBERG, M A *J. Fd Sci.*, 1963 **28**, 286.

CONNELL, J J *J. Sci. Fd Agric.*, **13**, 607. 1962

HANSON, S W F and OLLEY, J In *The Technology of Fish* 1965 *Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 111.

JONES, N R In *Recent Advances in Food Science*, Commodities, 1962 ed. J. Hawthorn and J. Muil Leitch, Butterworth, London, **1**, 151.

JONES, N R *Proc. XI Int. Congr. Refrig.*, Munich, IV–5. 1963

JONES, N R In *Fish Handling and Processing*, Paris, OECD, 1965a p. 31.

JONES, N R *Proceedings Flavour Chemistry Symposium*, 1965b Oregon State University, Westport, Conn., The AVI Publ. Co. (In press)

JONES, N R In *Fish Quality at Sea*, World Fishing and the 1965c White Fish Authority, London, p. 81.

KELLY, K, JONES, N R, LOVE, R M and OLLEY, J *J. Fd* 1966 *Technol.*, **1**(1), 9.

MCDONALD, I and JONES, N R Unpublished data, Torry 1967 Research Station, Aberdeen.

OLCOTT, H S In *Symposium on Foods: Lipids and their* 1962 *Oxidation*, ed. H. W. Schultz, E. A. Day and R. O. Sinnhuber, The AVI Publ. Co., Westport, Conn.

PARTMANN, W and GUTSCHMIDT, J *Kältetechnik*, 15, 130, 170, 1963 200.

RANKEN, M B F *Annex 1961–3 Bull. int. Inst. Refrig.*, 461. 1961

RANKEN, M B F In *Fish Quality at Sea*, World Fishing and 1965 the White Fish Authority, London, p. 57.

SALE, P F C *Ibid.*, p. 94. 1965

SEALEY, B *Ibid.*, p. 93. 1965

SHEWAN, J M In *Recent Advances in Food Science*, Commodi- 1962 ties, ed. J. Hawthorn and J. Muil Leitch, Butterworth, London, **1**, 167.

TARR, H L A *J. Fd Sci.*, **31**(6), 846. 1966

Condition of Fish and its Influence on the Quality of the Frozen Product

by R. M. Love

Condition of fish and its influence on the quality of the frozen product

The texture of newly-frozen fish, eaten after thawing and cooking, is not a fixed standard, but can vary according to the season and fishing ground and to the size of the fish. Thawed fish also "gape" in varying degrees, much gaping rendering the product unsaleable.

This paper is an attempt to examine the relevance of a number of inter-relating properties of cod to either of these two parameters, which are aspects of the acceptability of the final product.

It was concluded that the sole factor governing the texture of the material was depletion; the higher the protein and lower the water content, the firmer the product, and vice versa. A high pH, also symptomatic of depletion, was similarly characteristic of a softer product.

A curious result of the investigations was that the more depleted fish gaped less after filleting than the well-fed ones. This might be a special peculiarity of the grounds fished but, on the basis of the present evidence, gaping is not as likely to be linked to depletion as was formerly supposed.

The dynamics of the different factors was followed by starving a group of locally-caught cod in an aquarium.

Etat du poisson et son influence sur la qualité du produit congelé

La texture du poisson congelé récemment et consommé après décongélation et cuisson ne répond pas à un critère fixe, mais peut varier d'une part selon la saison et le terrain de pêche, de l'autre selon la taille du poisson. Le relâchement des tissus du poisson décongelé est également variable, son excès rendant le produit invendable.

Le présent document a pour but d'examiner le rapport entre un certain nombre de propriétés interdépendantes de la morue avec chacun de ces deux paramètres, ces propriétés constituant des aspects de l'acceptabilité du produit final.

On a conclu que le seul facteur affectant la texture du produit était l'epuisement des réserves. Le produit était d'autant plus ferme que la teneur en protéine était plus elevée et la teneur en eau faible. Un pH élevé, également symptomatique de cet épuisement annonçait aussi un produit plus mou.

Fait curieux, il ressort des recherches entreprises, que les tissus des poissons les plus épuisés sont moins sujets au relâchement que ceux des poissons bien nourris. Il se pourrait que cela soit lié aux fonds de pêche; en tout état de cause, il semblerait que le relâchement tissulaire soit moins directement lié à l'épuisement qu'on ne le supposait dans le passé.

L'évolution des différents facteurs a été étudiée en privant de nourriture, dans un aquarium, un groupe de morues capturées à proximité.

Estado del pescado y su influencia sobre la calidad del producto congelado

La textura del pescado recién congelado, consumido después de descongelarlo y cocinado, no está sujeta a una norma fija sino que puede variar según la época, el lugar de pesca y el tamaño del pescado. El pescado descongelado se agrieta también en diversa medida, y cuando tal sucede en grado considerable, el producto resulta invendible.

En el presente trabajo se trata de examinar la importancia de algunas propiedades del bacalao que se relacionan entre sí con cualquiera de estos dos parámetros, que son aspectos de la aceptabilidad del producto final.

Se llega a la conclusión de que el único factor que rige la textura del material es la depauperación; cuanto más elevado es el contenido de proteínas y más bajo el de humedad, más firme es el producto y viceversa. Igualmente característico de un producto más blando es un pH elevado, síntoma igualmente de depauperación.

Constituyó un resultado curioso de las investigaciones, el hecho de que en el proceso del fileteado la carne de los peces más depauperados se agrietaba menos que la de los que estaban bien alimentados. Esto podría ser una peculiaridad de los caladeros en los que se capturaron pero, basándose en los datos de que se dispone, probablemente el agrietamiento de la carne no está tan relacionado con la depauperación como en un principio se supuso. Se observó la dinámica de los diferentes factores dejando de dar alimento en un acuario a un grupo de bacalaos capturado localmente.

TWO characteristics of fish muscle which are affected by freezing and cold storage are texture and appearance, and severe alteration in either renders the product unacceptable as food.

However, study of the mechanism of deterioration during cold storage can often be seriously hindered by the fact that the raw material before freezing is not of constant quality. A fish taken out of the sea can differ from others of the same species by variation in a considerable number of chemical, physical or morphological properties depending on size, fishing ground or the time of year (Love, 1965), and it was the object of the present work to measure as many of these as possible, and then attempt to relate them, after freezing and thawing, to the texture and appearance of the resulting fillets. Cod (*Gadus morhua* L.) was the fish used.

In order to cover as wide a range of fishing grounds as possible, two trips were made in the research trawler *Sir William Hardy*; in June 1965 to Faroe, Iceland, Bear Island and Norway, and in June 1966 to Faroe, Iceland, West Greenland and St. Kilda (west of Scotland), in addition to localities around the coast of Scotland. Appreciation of the results of the first trip was assisted by the use of a computer. The chemical analyses, etc., of the material of the second trip were completed only just before this paper was written, and so could not be treated in this way.

METHODS

The fish were measured and sexed immediately after catching, then gutted and placed in melting ice. After a day, one fillet was removed from each fish, and suitable samples were dissected out, wrapped in aluminium foil and frozen for the future determination of pH, total protein nitrogen, cell fragility and water content. The remaining fillet, still attached to the skeleton and head, was wrapped in aluminium foil and laid flat in a room on the ship at −30°C (−22°F) exactly 24 h after the fish had been caught. Great care was taken to prevent the

body from bending at any stage of the operation. After thawing in the laboratory at the end of the trip, the second fillet was removed from the skeleton, examined for gaping, and then cooked and tasted for texture changes.

The pH was measured after homogenizing 10 g of muscle with 20 ml distilled water.

Protein nitrogen was measured by the standard Kjeldahl procedure (micro-modification) after grinding a weighed sample with a glass rod in 15 per cent trichloroacetic acid, centrifuging and discarding the supernatant liquor.

Cell fragility determinations were carried out by the procedure of Love and Mackay (1962).

The water content of thawed samples was determined by weighing before and after drying at 100°C (212°F) for seven days.

Gaping, the lack of cohesion between myotomes, was assessed on an agreed five-point scale, "0" being no gaping at all, the fillet being perfectly smooth, and "4" showing so much that the fillet was virtually falling to pieces, spaces appearing in between almost every myotome.

For tasting, a piece of the anterior part of the fillet weighing about 300 g was steam-heated in a closed casserole for 30 min and tasted by six laboratory staff who, while not specially "trained", were accustomed to tasting frozen fish. A five-point scale of toughness was used, half-points being permitted: "3" represented "normal" fresh fish in good condition, more than three being tougher or firmer, less than three softer or more sloppy.

For artificial starvation, cod caught 20th September 1966 were kept in an aquarium at 9°C (48°F) without food for up to 11 weeks, four fish being killed each week and sampled for water content and pH.

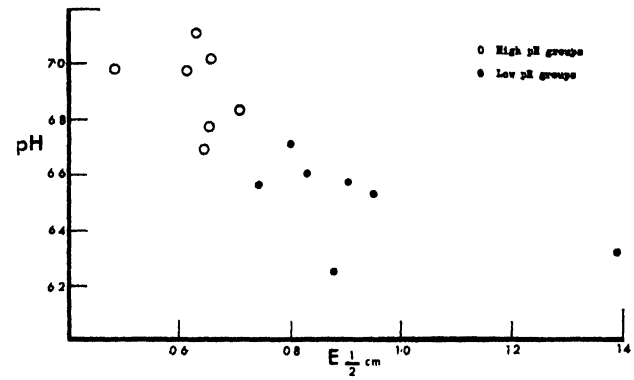


Fig 1. Relationship between the initial cell fragility values and the average pH of batches of fish from seven grounds. The cell fragility figures were obtained by extrapolating the statistical curves which best fitted the experimental values determined weekly for 15 weeks at −14°C (7°F)

TABLE 1. RATE OF DETERIORATION AT −14°C (7°F) AS MEASURED BY THE CELL FRAGILITY METHOD, OF THE MUSCLE OF COD OF HIGH AND LOW pH CAUGHT ON DIFFERENT GROUNDS

Fishing grounds	*Average high pH*	*Average low pH*	*Rate of reaction (units/week)*	
			High pH group	*Low pH group*
Bear Island	7.1	6.56	−0.11	−0.13
N. Lofoten (Norway)	7.01	6.70	−0.09	−0.13
Aberdeen	6.76	6.31	−0.18	−0.31
N. Scotland	6.96	6.55	−0.20	−0.24
S. Faroe	6.82	6.52	−0.12	−0.10
N. Faroe	6.97	6.55	−0.11	−0.12
S.E. Iceland	6.68	6.24	−0.18	−0.17
E. Iceland	6.89	—	−0.09	—
N.E. Iceland	7.14	—	−0.14	—
Minch (W. Scotland)	7.02	—	−0.15	—
North Cape (Norway)	7.21	—	−0.15	—

RESULTS AND DISCUSSION

Cell fragility, an objective test, in relation to pH and fishing ground

At each fishing ground on the first trip, 30 fish were filleted in 24 h after catching, and the pH of each fish was measured. The 10 fish with the highest pH and the 10 lowest were then used, the 10 intermediates being discarded. Each group of 10 fish was used to make 15 "mixed samples" (foil-wrapped bundles containing 10 pieces of fillet, each from a different fish) which were then frozen at −30°C (−22°F). On return to the laboratory, the "high pH" and "low pH" mixed samples were placed in a store at −14°C (7°F). One sample from each group was thawed each week at room temperature, taking about 1½ h and cell fragility determinations were done on each piece of fillet in the sample. In this way over 15 weeks a complete "denaturation" curve was made for high and for low pH fish from each ground.

It was clear that the initial value (0 week at −14°C, 7°F) of each curve which best fitted the experimental points was related to the average pH of the group (fig 1). Kelly *et al.* (1966) had previously noted this relationship, using individual fish.

In table 1 considerable differences can be seen between the reaction rates of fish from different grounds, but little effect results from differences in pH on the same ground. The only exception is in the group caught off Aberdeen, the rate of reaction being much greater at low pH. However, this particular curve is unusual anyway, and is shown in relation to the other low pH curves in fig 2, which illustrates how the slopes of the curves vary from ground to ground. The initial value of the "Aberdeen" curve is much higher than usually found (see also fig 2, where the point appears on the extreme right-hand side).

Thus, while the rate of deterioration measured by this technique is little affected by pH, the fishing ground exerts a measurable effect, the nature of which is at present unknown.

Subjective assessments of texture in relation to "condition"

When the texture (as tasted) was plotted against the water content of the fish (lower set of points, fig 3) a correlation ($r = -0.42$ with 276 points from individual fish) was obtained, showing that the water content could be used as a guide to the texture, provided that little cold storage deterioration had occurred. It has already been shown (Love, 1960, 1962) that when cod lose "condition" through starvation or spawning, the water content of the muscle increases as the protein decreases. Thus depletion softens the "eating" texture.

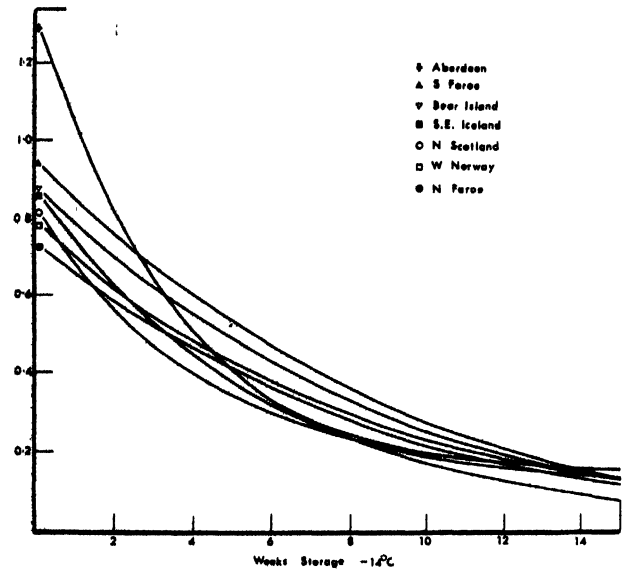


Fig 2. Statistical curves ("best fit" first order) showing the deterioration of low pH cod from different grounds, as measured by the cell fragility method, during storage at −14°C (7°F)

evenly throughout the diagram. This is presumed to be partly because of different nutritional conditions prevailing on the grounds; however, as with the rate of change of cell fragility with storage time (fig 2) the fish from each ground differ according to some additional factor. An example of this can be seen in fig 5, where taste score and pH are plotted by grounds. For a given pH the fish from St. Kilda are clearly firmer than those from, e.g. Fyllas Bank, Greenland. Now it was noticed that the St. Kilda fish were on the whole larger than those from Fyllas Bank, so possibly the effect is caused by size—it is hoped that computation will subsequently provide an answer to this.

A similar relationship existed between total protein nitrogen and texture as between water and texture, nitrogen and water being in inverse proportions.

Artificial depletion and its effect on pH and water content

In order to follow the change in water content and pH together under controlled conditions, some cod were held in an aquarium without food, four fish being killed and sampled each week. At the end of the experiments,

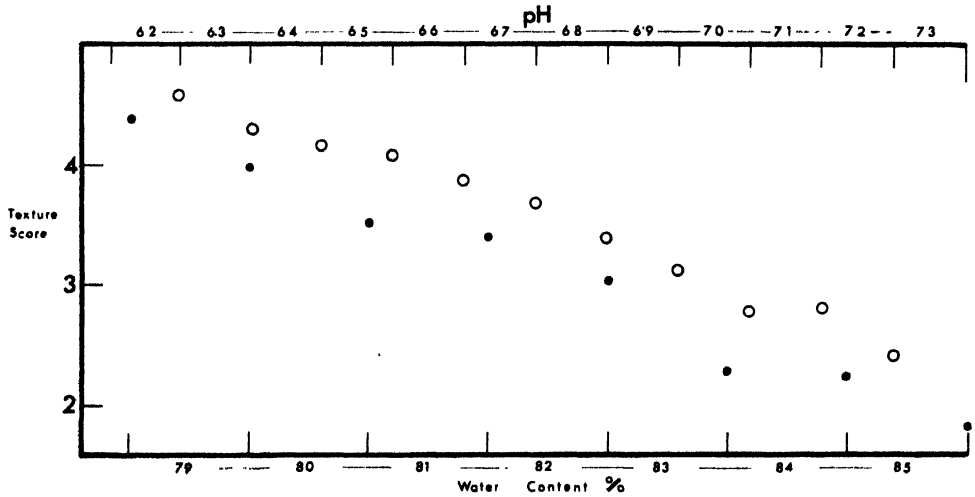


Fig 3. The relationship between the texture of cod muscle as tasted and the ultimate pH (hollow symbols). The texture scores are averages from cod ranging in water content from 78 to 78.99, 79 to 79.99 and so on. The cod were frozen at sea 24 h after death and stored for a few weeks at about −30°C (−22°F)

One might suppose that the pH of the muscle some 24 h after death was also related to depletion, since, if the carbohydrate reserves had been reduced, less lactic acid would be formed after circulation ceased, leaving the pH higher than in well-nourished fish. Kelly *et al.* (1966) showed that the softer the fish were to a taste panel, the higher was the ultimate pH, so the supposition appeared to be well-founded.

When in the present work the texture score was plotted against the pH (upper set of points, fig 3) a correlation was obtained ($r = -0.72$ with 276 points from individual fish) which was even better than that of the water/texture curve. When individual values of water content were plotted against pH, a correlation coefficient of +0.51 was obtained (fig 4). It was observed that whenever points relating to individual fish were plotted, as in fig 4, those relating to fish from different grounds tended to form definite groups, and were not distributed the ultimate pH and water-content were found to have followed each other closely (fig 6): both showed a small peak after six weeks, and both rose steadily beyond seven weeks. If in fact there is a direct relationship between water gain (or protein loss) and pH, then some re-thinking is necessary on the fate of carbohydrates in fish muscle after death. The relationship shown in fig 6 must, however, be considered as a preliminary finding which needs to be repeated.

The glycogen of cod liver has been shown to decrease steadily during starvation (Kamra, 1966), but plasma glucose, after a slight drop, is maintained at a steady level thereafter. Steady values or only moderate drops in blood glucose have also been reported during starvation

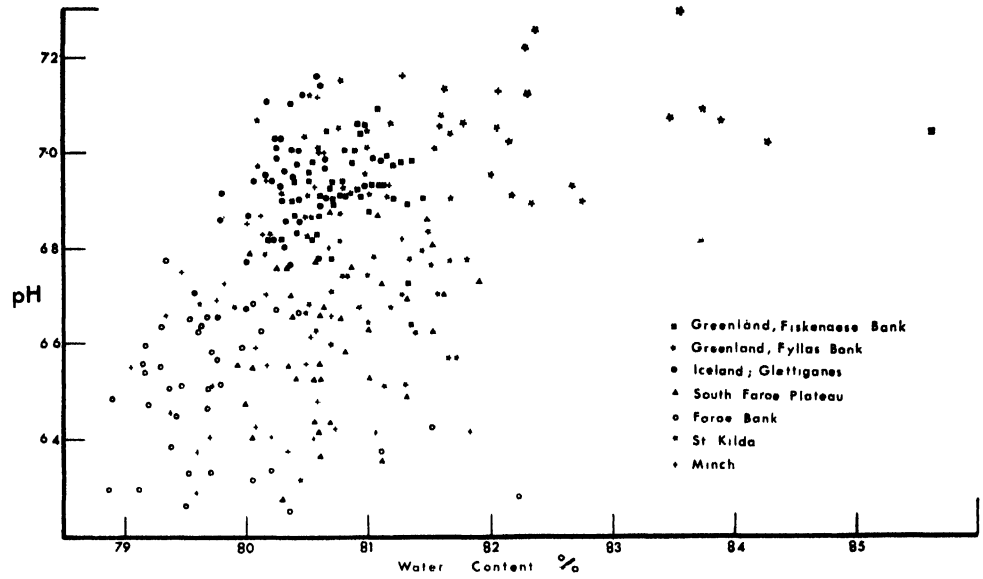


Fig 4. Relationship between the ultimate pH and the water content of the muscle of individual cod caught on various grounds

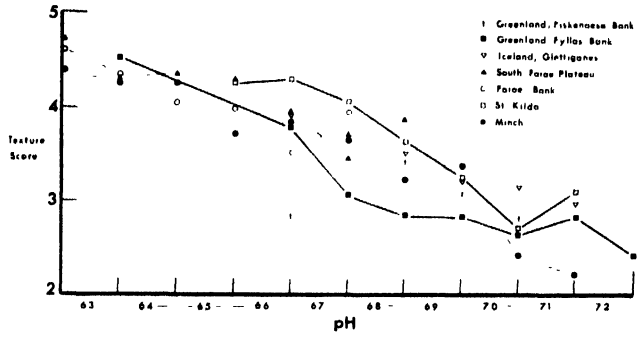


Fig 5. Effect of fishing ground on the relationship between texture as tasted and pH. The points are averages, and the system of drawing is the same as in fig 3

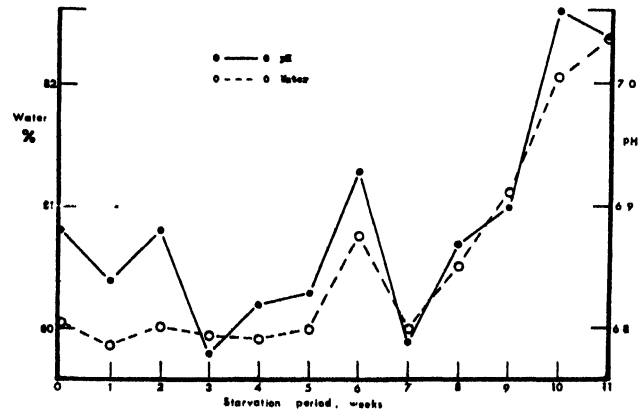


Fig 6. Water content and pH of the muscle of cod starved for increasing periods in an aquarium at 9°C (48°F)

in *Oncorhynchus tschawytscha* (Robertson *et al.*, 1961), *Myxine glutinosa* (Falkmer and Matty, 1966), *Notopterus notopterus* (Sundararaj *et al.*, 1966), *Lampetra fluviatilis* (Bentley and Follett, 1965), *Clarias lazera* (Al-Gauhari, 1958), *Salvelinus fontinalis* (Phillips *et al.*, 1953) and freshwater fish in general (Kiermeir, 1939).

We are more interested, in the present paper, in the changes in the carbohydrates of muscle but little information exists. While Sorvachev (1957) observed a reduction in the muscle glycogen of *Cyprinus carpio* during starvation, Bentley and Follett (1965) found that the muscle glycogen content of *Lampetra fluviatilis* was completely maintained even after five months without feeding.

The latter observation, coupled with those on glucose in the blood, shows that the level of carbohydrates in the muscle does not necessarily start to fall immediately after the cessation of feeding. If the relationship shown in fig 6 applies generally, then it would appear that the fish first draws on its liver glycogen reserves and in this way maintains the carbohydrate levels of blood and muscle. When the reserves are exhausted, the carbohydrate level of the muscle suddenly declines and so the ultimate pH rises; at the same time the protein level of the muscle begins to fall and water moves in to take its place.

Gaping in relation to "condition"

While fish in poor condition have in the past been said to gape more than healthy fish, it was noticeable in the present work that the fish which gaped a great deal one day after catching, from Faroe Bank, had in fact a low water content and firm texture when tasted. When ranges of water-content were grouped and plotted against subjective assessment of gaping (after freezing and thawing), a clear relationship appeared (fig 7). It appears that contrary to the traditional view, healthy fish gape more than depleted ones. The reason is unknown, although the possibility of the muscle of healthy fish contracting more strongly in *rigor mortis* and so breaking the connective tissue cannot be ruled out. This is, however, not the whole story: the actual thin sheets of connective tissue ("myocommata") from Faroe Bank fish were found, on dissection at the fish ground, to be very soft and gelatinous, but much firmer in fish from other grounds. This is all that can be said at present: clearly the problem of gaping is not a simple one.

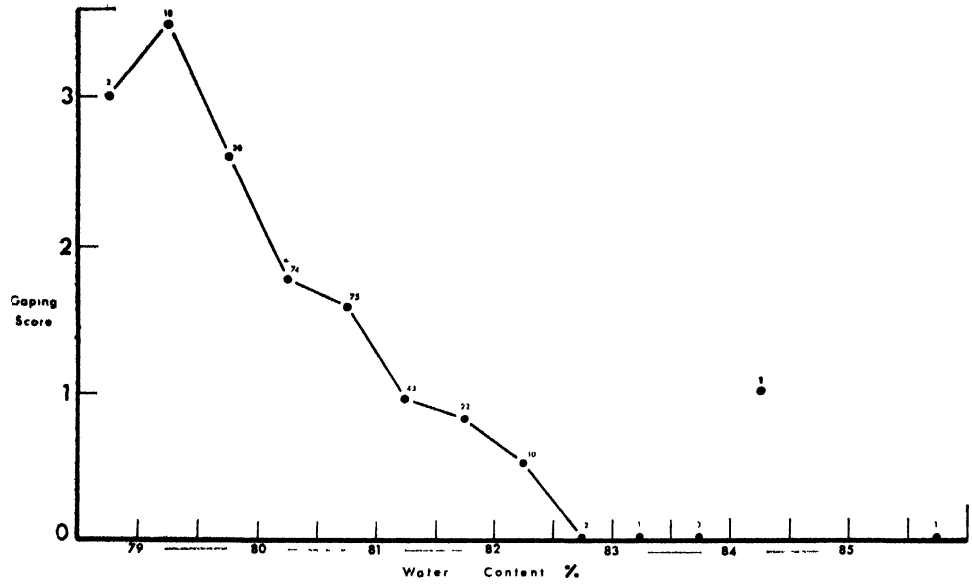


Fig 7. The amount of gaping of cod fillets in relation to the water content of the muscle (0, no gaping; 4, much gaping). The gaping scores were averaged for cod of water content 78.5 to 78.99, 79 to 79.45, 79.5 to 79.99 and so on. The small number beside each point refers to the number of fish averaged

CONCLUSIONS

The condition of fish varies widely between fish from different grounds and also from the same ground at the same time of the year. Condition can be assessed by measuring the water content or pH of the muscle, these two parameters being more closely linked than previously realized. Depleted fish taste softer than those in good condition, but appear to gape less than healthy fish.

Acknowledgments

The work described in this paper formed part of the program of the Ministry of Technology and Crown copyright is reserved. The author was assisted in the work by Messrs. I. Robertson, J. Lavety, A. Morrison, J. Smith and G. Pedersen, and by the Master of the *Sir William Hardy*, Mr. Arthur Whittleton.

ADDENDUM

Since this paper was written, the results of computation of some of the data have become available. In addition, the results illustrated in table 1 have been re-computed using the method of maximum possible likelihood. The findings are briefly summed up as follows:

(1) In fig 5 it was shown that the relationship between texture of cooked cod and pH was different for different fishing grounds. In the text of the paper it was hinted that perhaps the size of the fish was responsible, since some grounds yielded consistently large or consistently small fish.

Regression lines for three size-ranges of fish from all grounds mixed have been drawn, and in female cod there is a clear increase in toughness with size as well as the pH effect which is related to condition. A slide showing the relationship was exhibited at the Conference. However, male cod seem not to show this relationship, although almost equal numbers of male and female fish were examined. It is intended to repeat this work before drawing any firm conclusions about the sex difference.

(2) The computer program for the cell fragility values of the 1965 trip, shown in fig 2 of the paper, gave curves with different asymptotes (bottom of fig 2) which are unlikely considering the nature of the method. The new program gave a fixed asymptote, and it now seems probable that there are no significant differences between the rates of reaction (i.e. change per week at −14°C, 7°F) of cod from different fishing grounds—it has already been shown that fish of high or of low pH do not differ in this respect either.

Summary

The whole work appears to show that there is no genetic difference in cold storage behaviour of cod from different grounds, even though they may look different in shape and colour. The differences in "eating" texture or of cell fragility correspond with differences in nutritional state, and in addition there is a size effect which needs further investigation. Differences in gaping found in whole fish frozen 24 h after death, thawed and filleted, are evidently related only to condition.

References

BENTLEY, P J and FOLLETT, B K *Life Sci.*, **4**, 2003. 1965

FALKMER, S and MATTY, A J *Gen. comp. Endocr.*, **6**, 334. 1966

AL-GAUHARI, A E I *Z. vergl. Physiol.*, **41**, 26. 1958

KAMRA, S K *J. Fish. Res. Bd Can.*, **23**, 975. 1966

KELLY, K, JONES, N R, LOVE, R M and OLLEY, J *J. Fd* 1966 *Technol.*, **1**, 9.

KIERMEIR, A *Z. vergl. Physiol.*, **27**, 460. 1939

LOVE, R M *Nature, Lond.*, **185**, 692. 1960

LOVE, R M *J. Cons. perm. int. Explor. Mer*, **27**, 34. 1962

LOVE, R M In *The Technology of Fish Utilization*, ed. R.
1965 Kreuzer, Fishing News (Books) Ltd., London, p. 102.

LOVE, R M and MACKAY, ELEANOR M, *J. Sci. Fd Agric.*, 13,
1962 200.

PHILLIPS, A M, LOVELACE, F E, BROCKWAY, D R and BALZER,
1953 G C *Fish. Res. Bull. St. Wash.*, 16, Cortland Hatchery Rep. No. 21.

ROBERTSON, O H, DRUPP, M A, FAVOUR, C B, HANE, S and
1961 THOMAS, S F *Endocrinology*, **68**, 733.

SORVACHEV, K F *Biokhimiya*, **22**, 822. (English translation,
1957 N.Y.)

SUNDARARAJ, B I, KUMAR, M, NARASIMHAN, P V, PRASAD,
1966 M R N, VENKITASUBRAMANIAN, T A and MALATHY, J *Indian J. exp. Biol.*, **4**, 1.

Quality of Frozen Fish Fillets Influenced by the Freezing Process on Board Factory Vessels and the Cold Storage Ashore

by V. Meyer, N. Antonacopoulos and W. Flechtenmacher

Quality of frozen fish fillets influenced by the freezing process on board factory vessels and the cold storage ashore

The Institut für Biochemie und Technologie, Bundesforschungsanstalt für Fischerei, Hamburg, has prepared an investigation programme into deep-frozen fish which is an examination of the processing operation from a chemical, bacteriological and technological aspect.

The first part of the paper deals with the quality of fillets as they are affected by the processing conditions that occur in practice. It deals specifically with blocks of fillets as they are processed through vertical plate freezers. Factors were considered which affected the quality of the raw material and the various stages of handling and processing, for example, size and age of fish, time fish were held on deck without ice, degree of bleeding, freezing time, etc.

All samples were frozen to a core temperature of −28°C (−18°F). They were taken directly from the freezer and stored at −28° to −30°C (−18° to −22°F).

The influence on quality due to different processing techniques will be left to later investigation.

The variation of temperature inside the fillet blocks was examined during freezing and subsequent storage in the hold.

Influence sur la qualité des filets de poisson congelés des conditions dans lesquelles s'effectuent la congélation à bord et l'entreposage frigorifique à terre

L'Institut für Biochemie und Technologie du Bundesforschungsanstalt für Fischerei, de Hambourg, a mis sur pied un programme d'étude du poisson surgelé prévoyant l'examen des opérations de transformation sous leurs aspects chimique et technologique.

La première partie de la communication traite de l'influence qu'exercent sur la qualité des filets les conditions pratiques de la transformation et s'attache particulièrement aux blocs de filets surgelés dans des congélateurs à plaques verticales. Parmi les divers facteurs intervenant dans la qualité du produit fini avant le filetage et la surgélation figurent la qualité de la matière première, la taille et l'âge du poisson, ainsi que les circonstances de la manipulation, par exemple durée du séjour sans glace sur le pont, quantité de sang écoulée, etc.

Tous les échantillons ont été surgelés à −28°C (−18°F) (température à cœur). Prélevés directement dans le congélateur, ils ont été entreposés à une température variant de −28° à −30°C (−18° à −22°F).

L'influence sur la qualité des différentes techniques de transformation fera l'objet d'une étude ultérieure.

Les variations de température à l'intérieur des blocs de filets ont été étudiées tant durant la congélation que pendant le stockage ultérieur en cale.

Influencia del proceso de congelación a bordo de los buques factoría y del almacenamiento refrigerado en tierra sobre la calidad de los filetes de pescado congelado

El Institut für Biochemie und Technologie, Bundesforschungsanstalt für Fischerei de Hamburgo, ha preparado un programa de investigación del pescado congelado a altas temperaturas que constituye un examen del proceso de elaboración desde un punto de vista químico y tecnológico.

La primera parte del trabajo trata de la medida en que las condiciones de elaboración, como se producen en la práctica, influyen en la calidad de los filetes. Se ocupa específicamente de los bloques de filetes tal como se elaboran mediante congeladores de placas verticales. Se estudian también otros factores que se considera que influyen en el producto final antes del fileteado y de la congelación, como son la calidad de la materia prima, con respecto al tamaño y edad del pez, así como factores relacionados con la elaboración, tales como el tiempo en que el pescado estuvo en cubierta sin hielo, el grado de sangrado, etc. Todos los ejemplares se congelaron a una temperatura en el centro de −28°C (−18°F). Se tomaron directamente del congelador y se almacenaron a temperaturas de −28 a −30°C (−18 a −22°F).

Posteriormente se investigará el modo en que las diferentes técnicas de elaboración influyen en la calidad. Durante la congelación y el almacenamiento posterior en la bodega se examinó la variación de temperatura en el interior de los bloques de filetes.

CONSUMERS of sea-frozen fish fillets will often notice a difference in quality. This is due, as we know, to both the quality of the raw material and the various factors influencing the product before and after freezing.

Without an exact knowledge of the original quality of the fish, and also of the conditions of processing and subsequent storage, an estimation of the keeping quality of the frozen product is not possible (Banks, 1962; Dalhoff and Jul, 1963)

FACTORS INFLUENCING THE QUALITY OF THE FINAL PRODUCT

Effects of the raw material

The condition of fish immediately after catching depends on numerous factors such as fishing grounds (Love, 1964), state of nutrition (Love, 1958b), and conditions relating to feeding (Idler *et al.*, 1964). According to Love (1957), Tarr (1958), Jaquot (1961) and others, these biological factors affect also the chemical composition

of fish, as do other factors such as influences of season, maturity and age of fish. Heiss (1954) indicated that small fish, owing to their relatively larger surface and the larger amounts of slime, tend to spoil more rapidly.

Effects of handling prior to freezing

Other factors influence the fish during handling prior to freezing. Spoilage can occur, e.g., if the freshly-caught fish is held too long on the working deck, especially at elevated temperatures. Fish already gutted is particularly susceptible to spoilage by intestinal bacteria.

Jones (1965) found that poor bleeding will produce unfavourable results. The optimum bleeding should be 30 to 60 min at 0° to 5°C (32° to 41°F). Cutting the throat is very effective in shortening the bleeding time, especially if the fish has not been gutted and the beating of the heart speeds-up the bleeding process.

During filleting and skinning the naturally sterile muscle-tissue of the fish is cut and consequently exposed to contamination by bacteria. This will occur to some extent regardless of whether the operation is carried out by hand or by machine.

The quality of the raw material is, however, affected by the temperature at which it is held between the time of catching and freezing. The rate of spoilage prior to freezing increases with the rise in temperature, as has already been shown quantitatively by numerous investigations.

The relation between spoilage rate and temperature rise was observed for cod (*Gadus morhua*) by Heiss (1954), Kuprianoff (1955) and Bramsnaes (1964). If lean fish is delayed at 20°C (68°F) for 16 to 18 h before cooling down to 0°C (32°F), quality is kept for only half as long as when immediate cooling down to 0°C (32°F) takes place. The subsequent keeping quality of fish will be less when it is frozen in bad condition.

Effects of the freezing process

The freezing process can also affect the quality of the product. It is, therefore, necessary that the range of maximum crystallizing be passed through with sufficient speed, otherwise deteriorations in the texture, caused by protein denaturing, may occur, principally in the temperature range between 0° and −5° to −6°C (32° and 23° to 21°F) (IIR, 1964; Kuprianoff, 1955).

According to investigations carried out by Love (1955–58) and Love (1958a), damages to the cell structure of fish fillets occur in the region of maximum crystallization, not only at low, but also at high freezing rates. This is the case whether the cooling time between 0° and −5°C (32° and 23°F) is 25, 80, 200 or 500 min.

Dyer (1964) found that after freezing a temporary warming up to temperatures at which activation or acceleration of reactions takes place, may cause a decrease in quality. In the case of cod a temporary heating from −18°C (0°F) to above −15°C (5°F) may have such an effect.

In this respect the usual defrosting before the discharge of fish blocks from a vertical plate freezer has to be given special attention. Defrosting, though undesirable from the quality point of view, is an indispensable part of the process. The defrosting ensures that the subsequent charge will make good contact with the freezing plates, as well as facilitating the discharge of fillet blocks, having them stick to the freezer. It also enables the production of nearly "void-free" blocks (Pearson, 1965). Although the freezing plates are heated for only a comparatively short time to a little above the freezing point (60 to 90 sec with the temperature of the defrosting medium in the plates being about 30°C (86°F)), the frozen product is unfortunately heated considerably, especially at its surface.

Critical rises in temperature of 8° to 9°C/min (14° to 16°F/min) have been measured 8 mm ($\frac{5}{16}$ in) below the surface during the defrosting of 60 mm ($2\frac{3}{8}$ in) thick cod fillet blocks in paraffin paper boxes (Flechtenmacher, 1967). Depending on the degree of sub-cooling prior to defrosting, it is possible for temperatures of over −15°C (5°F) to develop in the product.

Effects of handling after freezing and storage before distribution to the consumer

Further temperature rises in the frozen product are caused by elevated ambient temperature during movement between the freezer and the hold. This is especially the case when handling the product in frozen condition in the distribution chain (wholesale warehouse, distributing store, shop refrigerator). This temperature rise must be compensated for by additional sub-cooling in the freezer.

According to Torry Research Station (1965) exposure of frozen consumer packs at between −29° and −7°C (−20° and 19°F) to warm ambient temperatures can cause their temperature to rise at a rate of 0.52°C/min (1°F/min). According to *Die Kälte* (Anon. 1963) the rate is 0.82°C/min (1.5°F/min) for 400-g packs initially at between −23° and −12°C (−9° and 10°F). In the case of cod fillet blocks with dimensions of 400 × 450 × 60 mm (16 × 18 × $2\frac{3}{8}$ in), initial temperatures of between −40° and −23°C (−40° and −9°F), and an ambient temperature of about 15°C (59°F), the rate of warming up was on the average of 0.5°C/min (0.9°F/min) in 10 to 15 min after the discharge from the vertical plate freezer; 30 min after the discharge and a product temperature of −20°C (−4°F) it was 0.2° to 0.4°C/min (0.35° to 0.7°F/min) (Flechtenmacher, 1967). The defrosting has a particularly unfavourable effect since the subsequent warming of the product on exposure to the ambient temperature commences at a higher temperature.

In addition, low air humidity and fluctuations in temperature during long storage periods can cause "freezer burn". According to IIR (1964) considerable damage from "freezer burn" may result if there has been enough dehydration to cause a weight loss of 0.5 per cent in consumer packs.

Dynistra observed that apart from dehydration, normal fluctuations of cold storage temperatures do not result in the decreases in quality, usually associated with temperature rises. Consequently, except for "freezer burn", the effect on quality of a fluctuating cold room temperature will be similar to that of the average temperature for the respective period.

PROBLEMS OF QUALITY DETERMINATION OF FROZEN FISH

The problems concerning the objective determination of quality of quick-frozen fish were outlined by several authors during the last FAO Symposium at Husum, May 1964. Gould (1965) also pointed out that in spite of great efforts on the part of many experts, it has not so far been possible to develop satisfactory objective methods which are in accord with the taste panel assessment. In the case of marine fish the complicating factor is that, unlike most other food products of animal or vegetable origin, the original quality of the raw material is beyond human control.

EXPERIMENTAL PROGRAMME

Quality assessment

The Institut für Biochemie und Technologie [Institute of Biochemistry and Technology] of the Bundesforschungsanstalt für Fisherei [Fisheries Research Board of the Federal Republic of Germany] in Hamburg has been for some time engaged in the assessment of the quality of frozen fish. The work of the last few years has been mainly confined to the problems of organoleptic determination of consumer packs, supplemented by the determination of drip loss and volatile bases (Antonacopoulos, 1965). Because of the growing importance of frozen fish on the German market, the expansion of the fleet of factory vessels and, last but not least, inspired by the Department of Fisheries of FAO, a "Deepfrozen Fish Investigation Program" to be carried out by the Institute, has been prepared. This will not only increase our knowledge about frozen fish products, but will also furnish data to improve processing methods, quality and keeping time as well as methods of quality evaluation.

In order to successfully assess the effect on quality, of the nature and condition of the fish on the one hand and the conditions of handling, cold storage and distribution on the other, the following requirements must be met:

(1) Suitable methods for testing quality are necessary. Apart from the taste panel method, a variety of objective analytical methods must be employed to indicate as many of the decomposition processes and decomposition components as possible.

(2) The condition of the raw material used for the freezing experiments must be known and controlled. This can be done by a selection of fish of a similar type as to length, weight, freshness, etc., tested also by chemical and physical methods. The storage in ice of the type of fish used will yield some further information on its quality as a raw material.

(3) Quick freezing and cold-storage plants.

(a) Pilot freezing plants with a wide range of temperature adjustment (−20° to −60°C; −4° to −76°F), and with adjustment for freezing layers varying in thickness from 60 to 200 mm (2⅜ to 8 in).

(b) Temperature recording devices to relate the temperature during processing and storage to the quality changes in frozen fish.

Applied methods. For quality assessment the familiar methods of testing the degree of freshness of wet fish, such as the estimation of pH, trimethylaminoxide (TMAO), trimethylamine (TMA), volatile basic nitrogen (VBN) and volatile reducing substances (VRS) were used. Other tests were: dry weight (water content), raw protein (in the flesh and expressible fluid), free and bound amino acids (e.g., of soluble protein), optical density of the expressible fluid, etc.

It was also important to know whether these methods could be employed aboard the vessel. If not, methods for the fixing of the material (condition at time of sampling) for a later examination ashore would need to be found and tested. Some of the above-mentioned methods have already been modified and simplified. Several methods for indicating quality changes, and their modifications, need to be compared. Therefore, to begin with, simple and quick methods, suitable for an extensive test series were chosen.

The taste panel method used as a control is a 20 score-point scheme modified in accordance with the regulations of the Deutsche Landwirtschafts-Gesellschaft [DLG German Agriculture Society]. In this scheme, five points are used to rate the appearance (thawed and cooked), 10 points for odour, flavour (flesh and fluid) and the consistency and the remaining five points to rate analytical evaluation. During the actual examination each criteria can get a maximum mark of five (excellent). However, in the final evaluation, the rating for each factor is weighted according to its significance.

Example: mark $\frac{3}{5} \times 2 = 1.2$ score-points.

The chemical investigations are supplemented by bacteriological tests and tests showing the effect of processing and storage conditions.

Quick-freezing and cold-storage plants

The quick-freezing plants installed aboard the FRV *Walther Herwig* to carry out the experimental programme, are of the most modern type, generally used on F. R. German fishing and factory vessels. The vertical plate freezers have aluminium freezing plates and use refrigerant R22 by pump recirculation. Each has its own refrigerating cycle. Both plants are equipped with a device for the continuous adjustment of the evaporation temperature, down to −60°C (−76°F).

These plants produce frozen fish blocks, 400×450 mm (16×18 in) in size. One freezer produces blocks 60 mm (2⅜ in) thick, but the other can produce frozen blocks of 100, 150 or 200 mm (4, 6 or 8 in) thickness. Both have the usual hot gas defrosting system.

There is also an automatic temperature recording device on board the vessel to measure the temperature inside the fish during the freezing process and during subsequent cold storage. Two recorders each with 12 measuring points, and having an adequate measuring range are connected to sockets on the working deck and beside the holds. By connecting resistance thermometers by 8 m (26 ft) long cables the temperatures measured in the plate freezers and in the holds (−28° to −30°C; −18° to −22°F) can be transmitted to the recorders.

Fig 1 shows one of the two vertical plate freezers with the resistance thermometers inside the product. Fig 2 shows the cables connecting the thermometers to sockets on the working deck. Fig 3 shows the sockets and the cables leading to one of the holds.

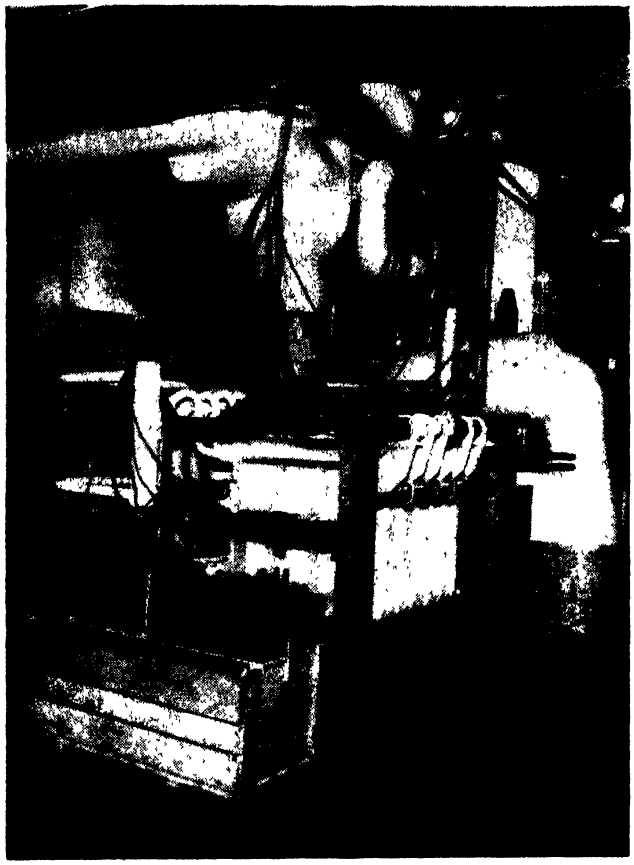


Fig 1. Vertical plate freezer aboard FRV Walther Herwig

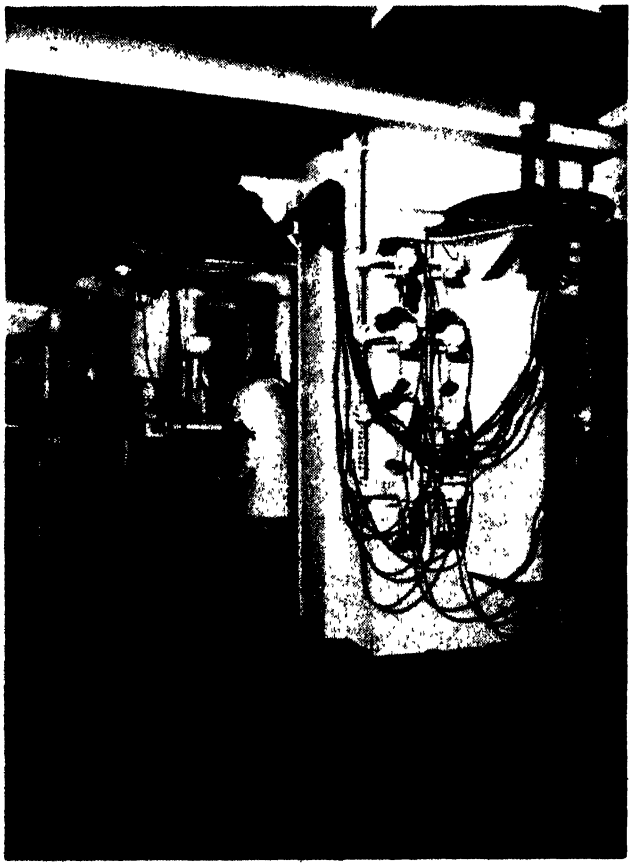


Fig 2. Connecting system recorder—resistance thermometers—vertical plate freezer aboard FRV Walther Herwig

Fig 3. Connecting system recorder—resistance thermometers—hold aboard FRV Walther Herwig

STATE OF INVESTIGATIONS

Experiments were made during two research trips aboard the FRV *Walther Herwig*. The investigations were carried out on cod (*Gadus morhua*) from the fishing grounds of the southern North Sea (first trip west of Denmark; second trip north of Channel entrance).

A pre-selection of material for quality assessments was made according to size (length) and weight of gutted fish, and by measurements with the "Fish Tester V" (Hennings, 1963). This was supplemented by chemical and bacteriological investigations to obtain basic analytical data. In addition, "storage in ice" experiments were carried out to assess the quality and the heterogeneity of the material used for freezing experiments, and to test the analytical methods.

For quality investigations, the following experiments were carried out:

(1) Two "storage in ice" experiments with whole gutted fish. During the first trip the samples were taken from unsorted fish, but during the second trip medium-sized cod, which was most abundant in the catch, was used.

One "storage in ice" experiment with fillets from medium-sized fish (second trip).

(2) Immediate freezing of cod fillets, during the first trip, from unsorted fish, and during the second trip, from three groups: big, medium-sized and small cod.

In addition, fillet blocks were produced from poorly-bled fish.

(3) Freezing of fillets from cod which was held on deck for varying times (7, 12, 18 and 33 h) without ice at ambient temperatures of between 15° and 20°C (59° and 68°F). This will show the changes in quality due in part to poor treatment of the fish. All freezing samples were frozen to a core temperature of −28°C (−18°F), taken from the freezer without defrosting and stored at −28° to −30°C (−18° to −22°F). Influences on quality by varying the processing techniques have been left for later investigations.

Along with the investigations on the processing technique, the changes in temperature at various points inside the fillet blocks were measured:

(a) during freezing;
(b) during manipulation between freezer and hold;
(c) inside the hold.

In all these three cases the products were exposed to the following varying conditions:

(i) blocks of different thickness were frozen in different packaging;
(ii) they were discharged from the freezer with or without defrosting;
(iii) after discharge from the freezer they were left in frozen condition for several hours on the working deck, at elevated ambient temperatures; other blocks were stored immediately after discharge from the freezer, with or without adequate sub-cooling, and finally, during cold storage, the temperature was oscillated between −20° and −30°C (−4° and −22°F).

Quality investigations

As these tests have just been completed, only a few results are available, some of which are given below.

Size and weight. Size and weight of the fish used is seen in fig 4 (unsorted cod—first trip) and in fig 5 (fish from three groups—second trip).

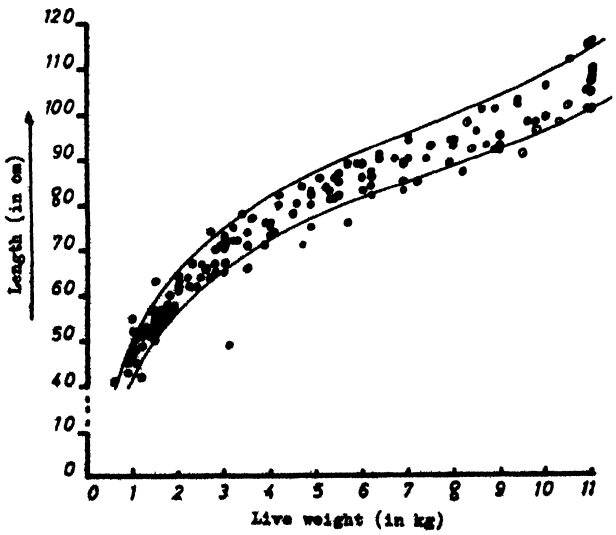


Fig 4. Relation between length and live weight of cod (unsorted fish)

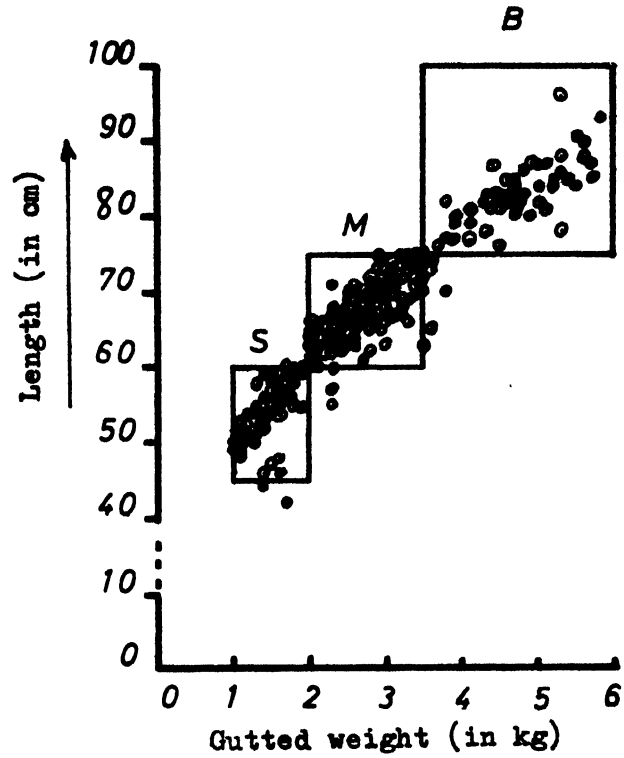


Fig 5. Relation between length and weight of gutted cod, divided into three groups: S, small (45 to 60 cm (18 to 24 in), 1 to 2 kg (2 to 4 lb)); M, medium (60 to 75 cm (24 to 29½ in), 2 to 3.5 kg (4 to 7 lb)); B, big (75 to 100 cm (29½ to 40 in), 3.5 to 6 kg (7 to 12 lb)).

Storage in ice. Figs 6 and 7(a) (whole gutted cod) and fig 7(b) (cod fillets) represent a comparison between the results of the taste panel assessment and some chemical data obtained during the storage on ice. Each point on these graphs represents the average value of duplicate determinations, one from each fillet of the same fish. Two fish were analysed on each day of sampling.

It is noted that the largest variations occur in the data for unsorted fish from the south-east North Sea on the twelfth storage day in ice (fig 6).

The higher values for VBN, TMA and VRS are mostly associated with the smaller fish which, as we know, tend to spoil rapidly. The variation is somewhat less for medium-sized cod from the south-west North Sea (fig 7(a)). The organoleptic examination of these fish showed, however, that deterioration in quality was more rapid during the first stage of storage. Fillets from medium-sized cod from the same fishing grounds (fig 7(b)) showed the same effects, but as was to be expected, deterioration of quality was, on the whole, more rapid. The different "storage behaviour" of cod caught in November 1966 west of Denmark, and in January 1967 in the Channel entrance, may be interpreted as due to the influence of the fishing grounds (compare Love, 1964). Further examples of this influence are given by "Fish-Tester V" measurements on board the FRV *Anton Dohrn*. According to these measurements cod stored immediately after catching had the following average storage life in ice: from catches near the Bear Islands South, 10.6 days; from south Greenland, 12.6 days; and from the Nordwestbank, 14.8 days.

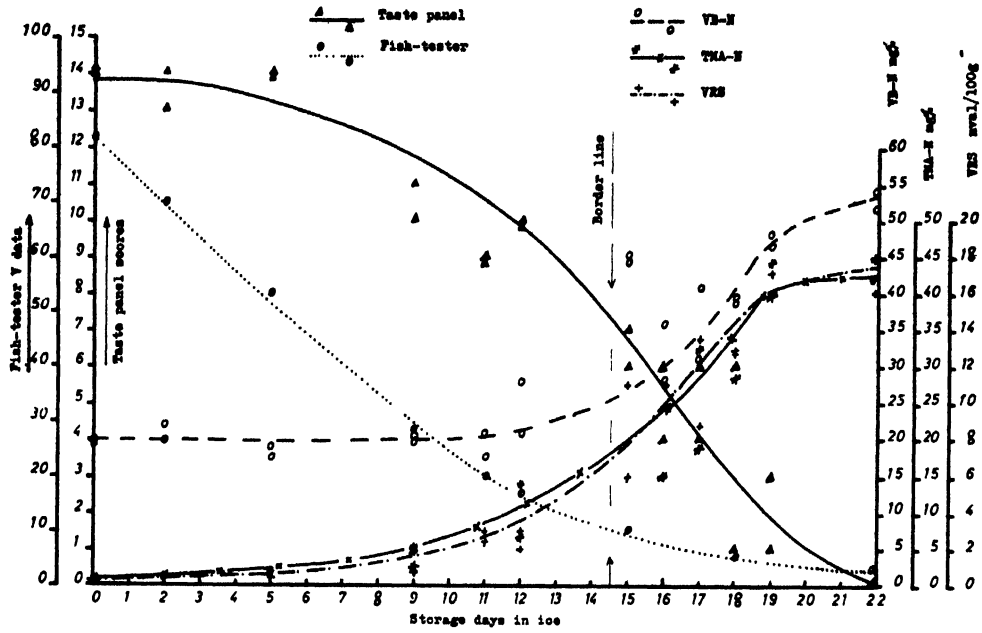


Fig 6. Quality changes in gutted cod (unsorted fish) during storage in ice (November 1966)

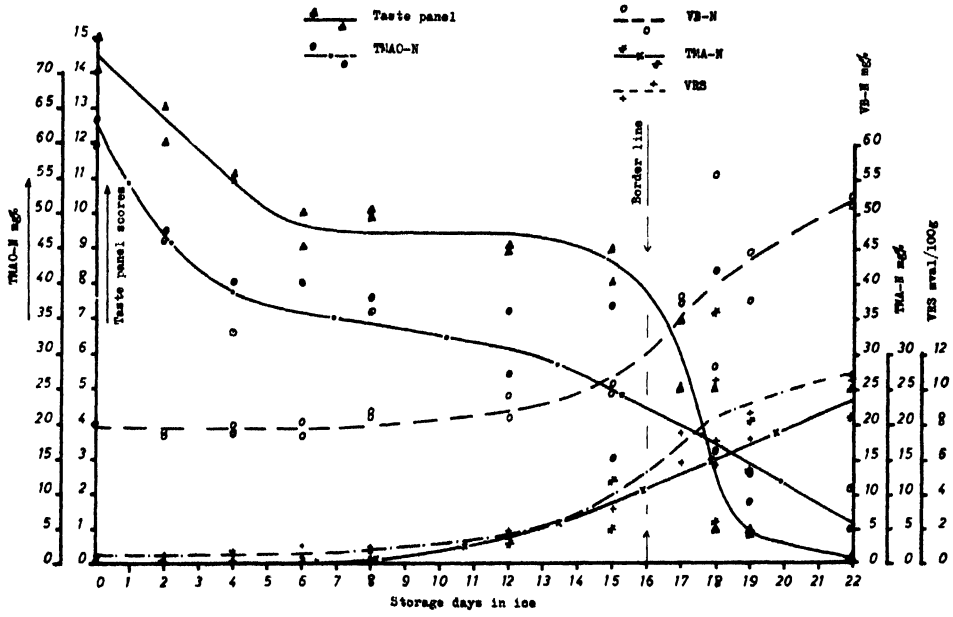


Fig 7(a). Quality changes in gutted cod (medium-sized fish) during storage in ice (January 1967)

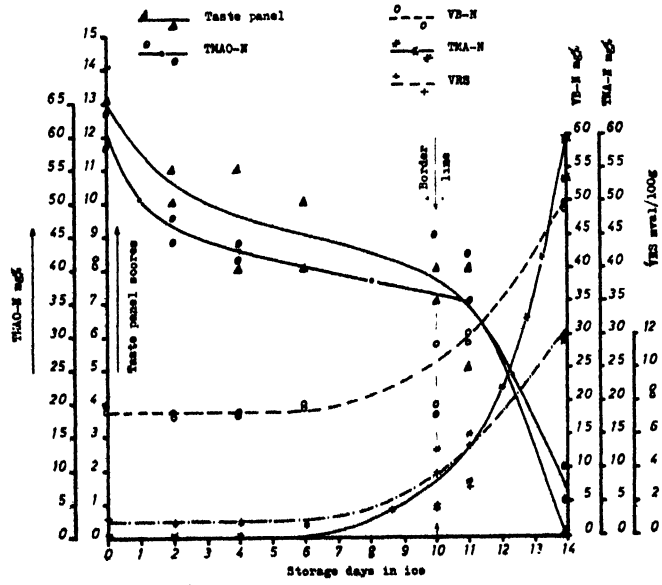


Fig 7(b). Quality changes in cod fillets (medium-sized fish) during storage in ice (January 1967)

No final conclusions can as yet be drawn from the few available results but a certain conformity is noticed in the various tests. The importance of parallel "storage in ice" experiments for the evaluation of initial quality of fish to be frozen can be deduced from this data.

Frozen storage. In this case also only a few results of organoleptic determinations are available. Only after a longer storage period will it be possible to evaluate how far the methods for the examination of wet fish can be applied to frozen fish. Fig 8 shows the results of the

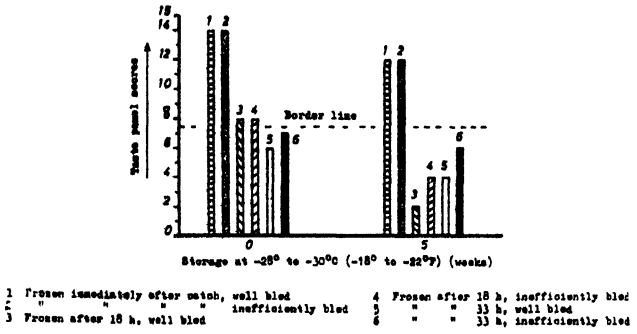


Fig 8. Quality changes in frozen cod fillets (unsorted fish) during cold storage (taste panel assessment)

organoleptic determinations for fresh frozen fillet blocks from well-bled and poorly-bled fish, unsorted and ungutted fish, and from fish filleted and frozen after a holding on deck without ice for 18 and 33 h at 15°C (59°F). These latter fillet blocks were practically of reject quality when entering storage. The poorly-bled fillets generally had a poor appearance, but in the beginning, at least, were rated well as to odour, flavour and texture.

The first results of organoleptic examination of frozen fillets from small, medium-sized and big cod are given in fig 9. Also shown are data for frozen fillets from fish

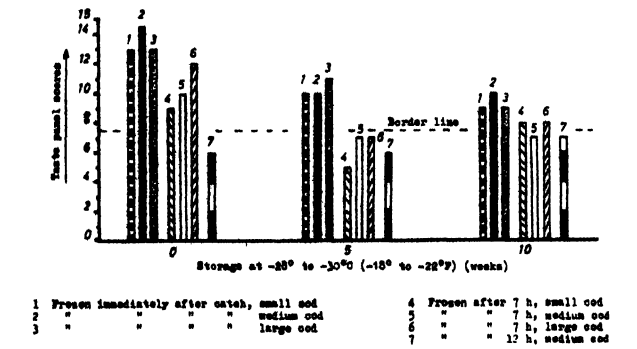


Fig 9. Quality changes in frozen cod fillets (small, medium and large fish) during cold storage (taste panel assessment)

gutted and then held on deck for 7 or 12 h. Differences, as seen in fig 8 and fig 9, may be due to the influence of the fishing ground or the biological condition of the fish.

Investigations of processing technique

The influence of the processing methods on the product temperature is shown by measurements carried out on board FRV *Walther Herwig* under conditions similar to those in commercial plants. These measurements were made on 60 or 100 mm (2⅜ or 4 in) thick cod fillet blocks with other dimensions of 400×450 mm (16×18 in).

Freezing rate. The length of time taken for the freezing and the sub-cooling of each sample product from 0° to −5°C (32° to 23°F) is shown in minutes in fig 10. The fillet blocks were frozen either unpacked or in paraffin paper cartons. The cartons were of sulphate semi-chemical material weighing 244 g/m² (0.05 lb/ft²) with a 40 g/m² (0·008 lb/ft²) coating of "Elvax" on each side, giving a total material thickness of 0.3 mm.

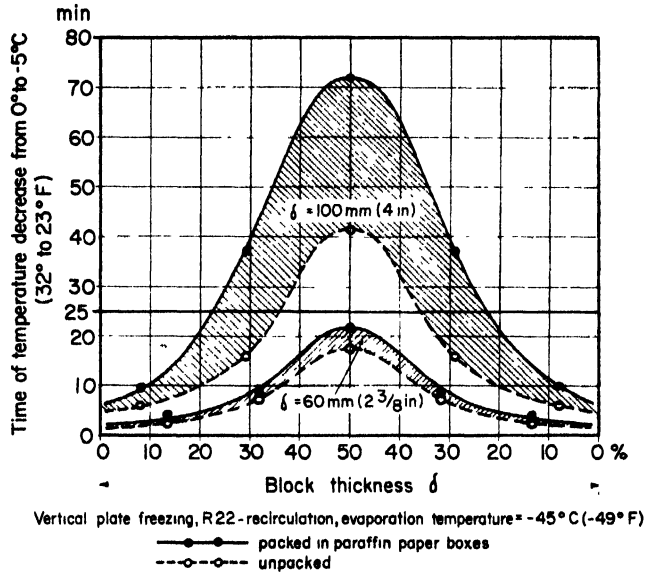


Fig 10. Freezing rate in cross-section of cod fillet blocks

It will be noted from fig 10 that, in some instances, the central part of the block required more than 25 min to cool through the temperature range between 0° and −5°C (32° and 23°F). This is considered unsatisfactory since the quality of the product will not be homogeneous throughout its cross-section. Variations in quality within blocks, due to this cause, will increase with product thickness.

Defrosting of vertical plate freezer. Fig 11 shows the temperature difference between the centre and 8 mm (⅜ in) below the surface of 100 mm (4 in) thick cod fillet blocks after discharge from the freezer with or without defrosting, as compared with similar measurements for 60 mm (2⅜ in) thick blocks recorded earlier (Flechtenmacher, 1967). This temperature difference is a measure of the effect of defrosting on the product since initial temperature differences between the centre and the surface are greater the thicker the product, and the warming up at the surface is independent of the product thickness. The greater the thickness of the product, the less serious the effect of defrosting. Considering that the product should be as thin as possible for a short freezing time and a high freezing rate, there exists an optimum product thickness to minimize the opposing effects of freezing time and defrosting process.

The determination of the optimum block thickness by Pearson (1965) for freezing fish in vertical plate freezers

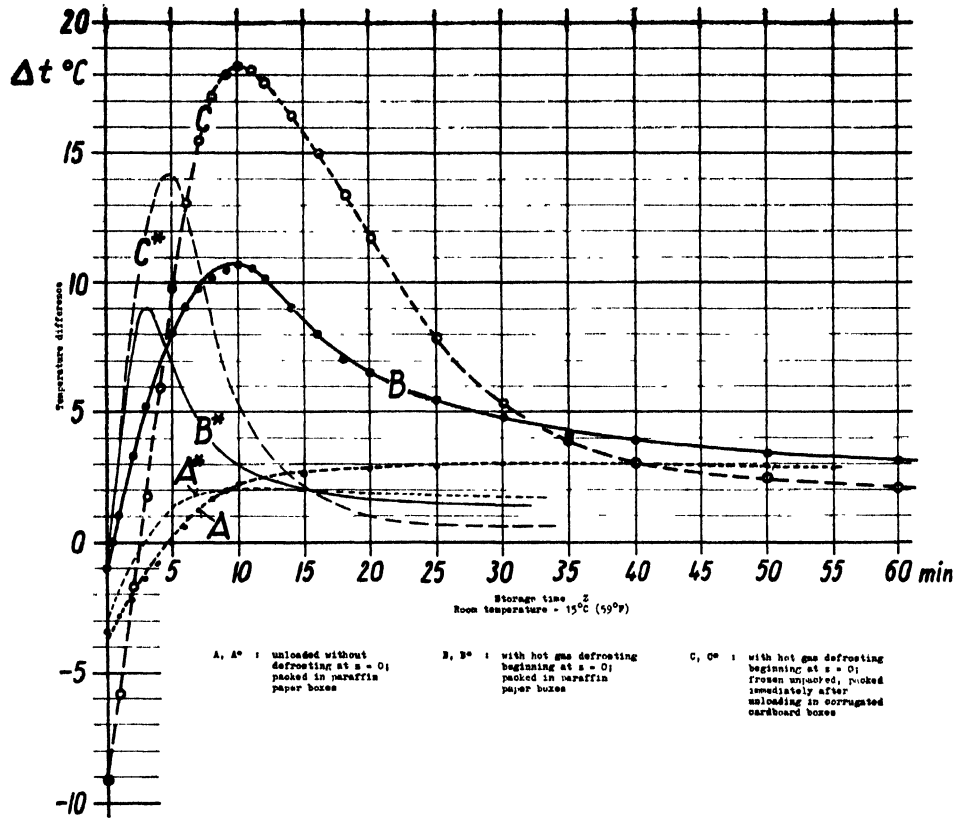


Fig 11. Temperature difference inside cod fillet blocks between core and 8 mm ($\frac{5}{16}$ in) below surface, immediately after unloading vertical plate freezer (60 mm ($2\frac{3}{8}$ in): A, B*, C*; 100 mm (4 in): A, B, C)*

does not take into account the possible influence of defrosting on quality. This optimum thickness is changed, if the influence of defrosting is considered. In this case, however, the extent of quality deterioration must quantitatively be known.

Heating of the frozen product by elevated ambient temperature. Fig 12 shows the length of time taken for frozen cod fillet blocks to warm through the temperature range of −15° to −5°C (5° to 23°F) when exposed to an ambient temperature of 15°C (59°F). The blocks were discharged from the vertical plate freezer either with or without defrosting. Temperature measurements were taken both at the centre and 8 mm ($\frac{5}{16}$ in) below the surface of the blocks. The considerably faster warming of the blocks which were discharged with defrosting of the plate freezer is due to the fact that the outer layers of the blocks had already been somewhat warmed by the defrosting.

Since the product is still solid at these temperatures (−15° and −5°C; 5° and 23°F) there is the danger that the fact that they have been warmed may be overlooked during handling the product. Consequently, warming that occurs during the sawing of frozen fillet blocks into small consumer packs may result in quality deterioration.

Finally, fig 13 shows the time-volume relation in the warming of 60 mm ($2\frac{3}{8}$ in) and 100 mm (4 in) thick frozen cod fillet blocks in wax cartons to at least −15° or −5°C (5° or 23°F) at an ambient temperature of 15°C (59°F). The smaller the portions, the faster the product is heated. It is, therefore, necessary to transport small packs in as large and compact piles as possible.

Frozen storage. For the determination of the influence of fluctuating storage temperature on the product it is essential to know the extent to which the temperature curve of the product depends on the storage temperature. For 60 mm ($2\frac{3}{8}$ in) thick cod fillet blocks packed respectively in wax paper or corrugated cardboard, and separately stored, fig 14 shows that time, peak and speed of temperature increase in the product are dependent on the corresponding values of the room temperature between about −20° and −30°C (−4° and −22°F). [Specification of corrugated cardboard used: inside wave of semi-chemical paper material 120 g/m² (0.025 lb/ft²) between two outer layers of liner, each 200 g/m² (0.04 lb/ft²) and 300 μ thick; paraffin film with 15 per cent "Elvax" 35 g/m² (0.007 lb/ft²), 50 μ thick, on the side facing the product, total thickness of the combination 34.5 mm ($1\frac{3}{8}$ in).]

The solid line in fig 14 shows the length of time, in units of hours, during which the temperature at the core of the frozen product will continue to rise following a rise, for a given duration of time, of the air temperature of the cold store. It will be noted that an upward fluctuation in air temperature causes an upward fluctuation of approximately the same duration in the temperature of the product (although, of course, there is a time lag).

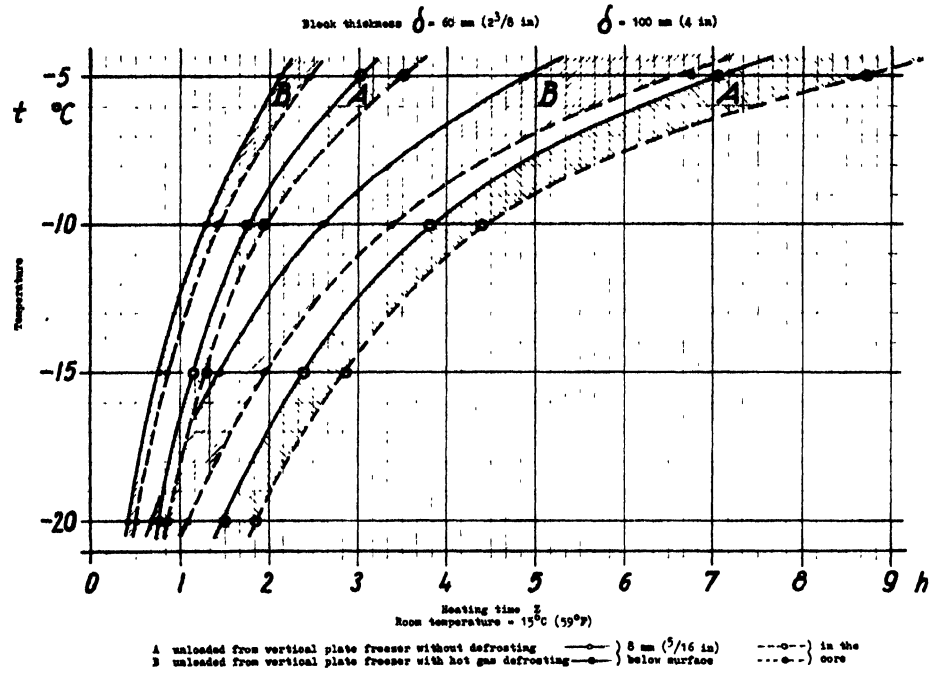


Fig 12. Heating of deep-frozen (approximately −35°C (−31°F) cod fillet blocks packed in paraffin paper boxes

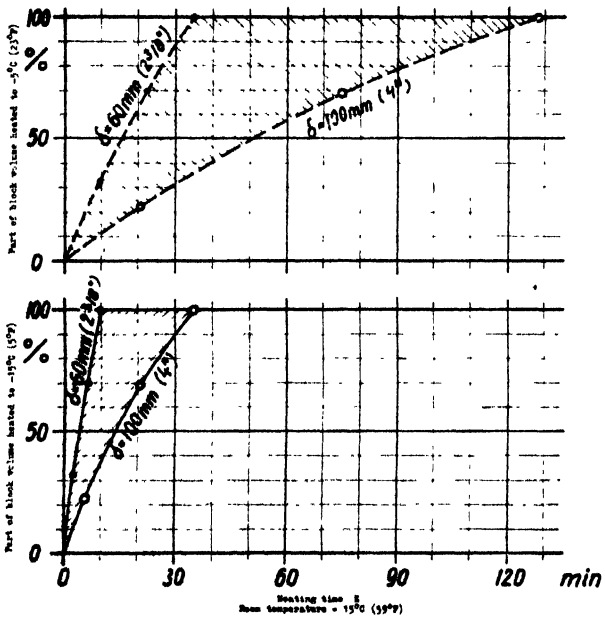


Fig 13. Heating of deep-frozen cod fillet blocks in paraffin paper boxes

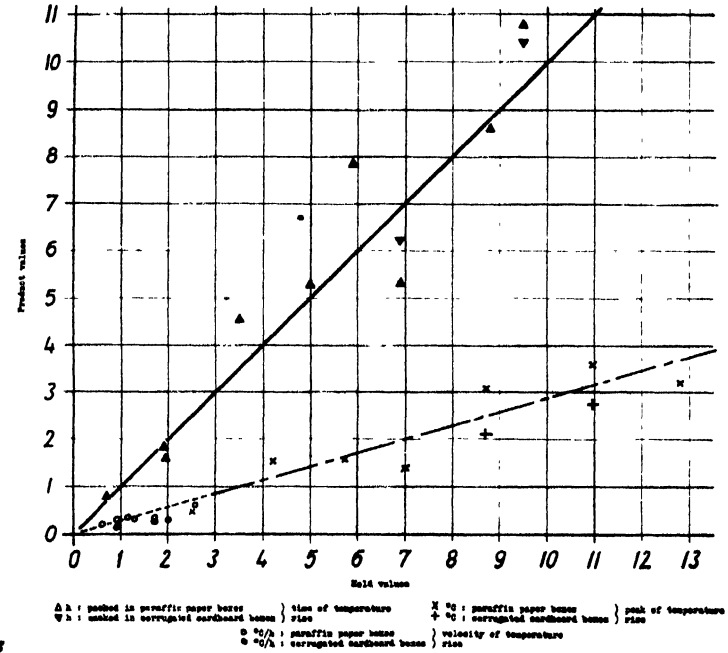


Fig 14. Temperature data of deep-frozen cod fillet blocks in the hold

The broken line shows, in °C, the approximate temperature rise in the product for a given upward fluctuation in the air temperature. The same curve shows the approximate rate, in units of °C/h, at which the product temperature will rise following a given rate of rise of the air temperature.

Regarding the peak and speed of temperature rises, conditions are more favourable in practice, with blocks stored compactly in large quantities, than with the blocks stored separately, as was the case in this experiment. On the other hand, however, the adaptation of product temperature to room temperature in the case of compact piles takes a longer time, and the blocks may be exposed too long to "critical" temperatures due to the supply of further inadequately frozen products.

FINAL REMARKS

The purpose of this paper was to outline the experimental Deep Frozen Fish programme of the Institut für Biochemie und Technologie of the Bundesforschungsanstalt für Fischerei, Hamburg, as a contribution to the

determination of the quality of frozen fish fillets. The experiments described are still in the preliminary stage. An extensive series of parallel experiments is, therefore, required before any definite conclusions can be drawn as to the effect of raw material, processing techniques, storage and distribution on product quality. These experiments should include both fat and lean fish.

With regard to the quality of sea-frozen fish fillets, further studies should concentrate particularly on the determination of quality changes at the beginning of storage. This would require more basic research to increase the still incomplete knowledge of the biochemical and microbiological decomposition processes in frozen fish.

The investigations of processing techniques indicate that the operating practices of the various plants have influence on product quality and suggest that these should, therefore, be closely examined. After freezing, the product is subjected to further treatments in the processing and distribution chain, which may affect its quality to a critical degree. In general, expert personnel are less available during the transport, interim storage and distribution stages than during the preparation, freezing and initial storage of frozen blocks.

Acknowledgments

The authors wish to acknowledge the contributions made to these investigations by Dr. E. K. Moustafa (in chemistry) and by Dr. H. Scheer and Dr. K. Stüven (in bacteriology).

References

ANON. 1963 Bericht über Tagung des Britischen Kälteinstituts in Grimsby, gemeinsam mit the Grimsby Institution of Engineers and Shipbuilders. *Die Kälte*, **16**(9), 490–495.

ANTONACOPOULOS, N 1965 Methoden der Qualitätsbeurteilung tiefgefrorener Fischerzeugnisse. *Infn Fischw. Auslds*, **12**(4/5), 180–185.

BANKS, A 1962 Identifying quality changes in frozen fish. *Annex* 1962–1 *Bull. int. Inst. Refrig.*, 445–454.

BRAMSNAES, F 1964 L'application du froid au poisson. *Annex* 1964–3 *Bull. int. Inst. Refrig.*, 143–156.

DALHOFF, E and JUL, M 1963 Factors affecting the keeping quality of frozen foods. *Proc. XI Int. Congr. Refrig.*, Munich, 1(57), 66.

DYER, W J 1964 Basic quality changes in frozen sea food. *ASHRAE Jl*, May, **6**(40–42), 101.

FLECHTENMACHER, W 1966 Mindestkerntemperatur von tiefgefrorenem Fisch. *Infn Fischw. Auslds*, **13**(6), 243–247.

FLECHTENMACHER, W 1967 Deepfreezing of fish fillets to blocks respectively consumer packs on board factory ships. XIIth International Congress of Refrigeration, Commission VIII, 30th August–6th September, Madrid.

GOULD, E 1965 Testing the freshness of frozen fish. Fishing News (Books) Ltd., London.

HEISS, R 1954 Stand der Forschung auf dem Gebiet der Behandlung u. Kaltlagerung v. Magerfischen. *Kältetechnik*, **6**(7), 183–189.

HENNINGS, C 1963 Ein neues elektronisches Schnellverfahren zur Ermittlung der Frische von Seefischen. *Z. Lebensmittelunters. u. -Forsch.*, **119**, 461.

IDLER, D R, MACCALLUM, W A, CHALKER, D and LANDER, J T 1964 Effect of environmental and/or physiological factors on quality. I. Newfoundland trap cod. In *The Technology of Fish Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 98.

INT. INST. REFRIG. 1964 Recommendations for the processing and handling of frozen foods. *Annex Bull. int. Inst. Refrig.*

JAQUOT, R 1961 Organic constituents of fish and other aquatic foods. In *Fish as Food*, ed. G. Borgström, Academic Press, New York, **1**, 145.

JONES, N R 1965 Freezing fillets at sea. In *The Handling and Care of Fish at Sea*, supplement to *Fishg News*, 13th August, and *Fishg News int.*, July–September, 40–46.

KUPRIANOFF, J 1955 Technische Probleme beim Gefrieren von Fischen. *Kältetechnik*, 7(8), 215–223.

LOVE, R J 1955 *J. Sci. Fd Agric.*, **6**, 30.

LOVE, R J 1956 *Ibid.*, **7**, 220.

LOVE, R J 1957 *Ibid.*, **8**, 238.

LOVE, R J 1958 *Ibid.*, **9**, 249, 257, 262.

LOVE, R M 1958a *Ibid.*, **9**, 609.

LOVE, R M 1958b Studies on the North Sea cod. 3. Effects of starvation. *J. Sci. Fd Agric.*, **9**, 616.

LOVE, R M 1964 The effect of different fishing grounds on the quality of frozen fish. In *The Technology of Fish Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 102.

PEARSON, S F 1965 Design and installation of refrigerating plant for freezing trawlers. *Annex* 1965–5 *Bull. int. Inst. Refrig.* 143–154.

TARR, H L A 1958 *A. Rev. Biochem.*, **27**, 223.

TORRY RESEARCH STATION 1965 Quick freezing of fish. *Torry Advis. Note*, No. 27, Aberdeen.

Condition of Newfoundland Offshore Fish and its Influence on Quality after Single and Double Freezing

by W. A. MacCallum, June I. Jaffray, Dorothy A. Chalker and D. R. Idler

Condition of Newfoundland offshore fish and its influence on quality after single and double freezing

The quality of single- and double-frozen stored cod (*Gadus morhua*), flounder (*Hippoglossoides platessoides*) and redfish (*Sebastes marinus mentella*) as determined by research laboratory and industry assessment, is reported with emphasis on *pre-rigor* freezing at sea, thawing ashore, packing with or without treatment with sodium tripolyphosphate (TPP), refreezing and storage at −23°C (−10°F).

The cod were exhausted after struggling in the otter trawl. Considerable variation was found in the quality of these cod *post-mortem* and this influenced the grades given the once-frozen pack after cold storage.

Work completed to date shows that *pre-rigor* freezing at sea and thawing and refreezing ashore resulted in acceptable or better refrozen quality in cod stored for upwards of one year while refrozen flounder and redfish were better still. Cod treated with TPP and twice-frozen were significantly better than untreated twice-frozen samples as indicated by texture and thaw-drip assessments and equal to once-frozen untreated fish. This could be the result of weakening of flesh consistency due to thawing with consequent presentation of increased surface areas of the fillet to the dip solution. There was no clear evidence of improvement in single- and double-frozen flounder after the application of TPP dips used commercially in processing this species [ratio of dip (of constant strength) to fish reduced from that used with cod]. Redfish were not studied in relation to TPP treatment.

Twice-frozen flounder appeared to have characteristics similar to those detected in once-frozen material and quality was independent of *pre-* and *in-rigor* freezing.

Chemical and organoleptic assessment showed no evidence of significant rancidity in unprocessed blocks of frozen cod stored unwrapped or during subsequent cold storage which followed thawing and reprocessing ashore.

Off-white colour (tending to a green hue) was noted in some thawed flounder. Tests on the fillets after refreezing and storage failed to show conclusively that differences in quality could be expected in processed refrozen fillets of these and normally white fish.

L'état du poisson pêché au large de Terre-Neuve et son influence sur la qualité après simple ou double congélation

La communication traite de la qualité, déterminée en laboratoire et industriellement, de morues (*Gadus morhua*), plies américaines (*Hippoglossoides platessoides*) et rascasses du Nord (*Sebastes marinus mentella*) entreposées après congélation simple ou double. L'accent est mis sur la congélation effectuée en mer avant la *rigor mortis*, la décongélation à terre, l'empaquetage avec ou sans traitement au tripolyphosphate de sodium (TPP), la recongélation et l'entreposage à −23°C (−10°F).

Les morues étaient épuisées après s'être débattues dans le chalut. De grandes différences ont été relevées dans la qualité *post mortem* de ces poissons, ce qui a influé sur les notes de qualité attribuées après entreposage en chambre froide des blocs congelés une seule fois.

Sur la base des travaux effectués jusqu'ici, la congélation en mer (avant la *rigor mortis*), suivie de décongélation et de recongélation à terre, donne une qualité acceptable ou bonne pour la morue entreposée plus d'un an, et encore supérieure pour la plie et la rascasse du Nord. La morue traitée au TPP et congelée deux fois s'est révélée d'une qualité nettement supérieure aux échantillons non traités et soumis à la double congélation (d'après l'évaluation de la texture et de l'exsudat à la décongélation), et égale au poisson non traité congelé une seule fois. Cela pourrait provenir de ce que le ramollissement de la chair consécutif à la décongélation met en contact avec le TPP une surface accrue de filet. Pour la plie américaine soumise à congélation simple ou double, il n'a pas été démontré d'amélioration marquée après application de la solution de TPP servant commercialement au traitement de cette espèce (bain de concentration constante, mais rapport volume du bain/poids du poisson inférieur à celui qui est employé pour la morue). La rascasse du Nord n'a pas été étudiée du point de vue du traitement au TPP.

La plie congelée deux fois a paru présenter des caractéristiques analogues à celles du matériel congelé une seule fois, le fait que la congélation soit intervenue avant ou pendant la *rigor mortis* n'ayant pas influencé la qualité.

L'analyse chimique et l'examen organoleptique n'ont pas révélé de rancidité notable dans les blocs non traités de morues congelées entreposés sans emballage, ni durant l'entreposage ultérieur en chambre froide ayant suivi la décongélation et le nouveau traitement à terre.

Certaines plies décongelées présentaient une teinte légèrement grisâtre (tirant sur le vert). Sur la base d'analyses des filets après recongélation et entreposage, il n'a pas été possible de conclure de manière probante à la possibilité de différences de qualité entre ces filets traités et recongelés et les filets de couleur blanche.

La condición del pescado de altura de Terranova y su influencia en la calidad despues del congelamiento sencillo y doble

Se presentan datos sobre la calidad del bacalao (*Gadus morhua*), la platija (*Hippoglossodes platessoides*) y la gallineta (*Sebastes marinus mentella*), almacenados después de congelación simple y doble, deducidos de pruebas en los laboratorios de investigación y de la experiencia de la industria, atendiendo preferentemente a la congelación en el mar antes de la rigidez, la descongelación en tierra, el envasado con o sin un tratamiento con tripolifosfato sódico (TPS), la recongelación y el almacenamiento a −23°C (−10°F).

El bacalao se hallaba exhausto después de luchar en la red de puertas. Se halló una variación considerable en la calidad de este bacalao *post-mortem*, lo que influyó en sus condiciones después del almacenamiento refrigerado del producto congelado una sola vez.

La labor acabada hasta la fecha indica que la congelación en el mar antes de la rigidez y la descongelación y recongelación en tierra dieron una calidad aceptable o mejor del bacalao almacenado durante más de un año, en tanto que la de la platija y la gallineta recongeladas fueron todavía mejores. El bacalao tratado con TPS y congelado dos veces fué mucho mejor que las muestras congeladas dos veces y no tratadas con TPS como lo indican las evaluaciones de la textura y el exudado es igual al pescado no tratado y congelado una sola vez. Esto podría ser el resultado de un ablandamiento de la consistencia de la carne debido a la descongelación, con la presentación consiguiente de mayores zonas de la superficie del filete a la solución de TPS. No se obtuvieron pruebas evidentes del mejoramiento de la platija congelada una o dos veces, al tratarla con el TPS empleado comercialmente al elaborar esta especie [la relación entre la inmersión (a concentración constante) y el pescado fué menor que la que se emplea en el tratamiento del bacalao]. La gallineta no se estudió en relación con el tratamiento con TPS.

La platija congelada dos veces parece poseer características similares a las detectadas en el material congelado una vez, siendo la calidad independiente de la congelación antes o después de presentarse la rigidez.

Las determinaciones químicas y organolépticas no dieron pruebas de ranciedad importante en los bloques no tratados de bacalao congelado y almacenado sin empaquetar o durante el posterior almacenamiento en frío que siguió a la descongelación y a la reelaboración en tierra. Un color blanco amarillento (tendiendo a verdoso) se observó en algunas platijas descongeladas. Los ensayos realizados con filetes vueltos a congelar y almacenar no demostraron de un modo concluyente que pudieran esperarse diferencias de calidad en los filetes elaborados vueltos a congelar de esta clase y, en general, de pescado blanco.

EARLIER work on offshore species showed the quality of cod at killing to be variable (MacCallum *et al.*, 1966), double freezing and storing cod (MacCallum *et al.*, 1966, 1967; Peters *et al.*, 1968), haddock (Peters and Slavin, 1960) and redfish (MacCallum *et al.*, 1967) to result in a product of marketable quality (and very high quality in the case of redfish) with slight preference in the assessment of twice-frozen stored cod being given to material originally frozen before *rigor*, rather than after three days iced storage (Peters *et al.*, 1968). The above authors and others, notably Borgstrom (1961) and Banks (1962), discuss inherent advantages of freezing (single freezing) before the development of *rigor mortis*.

The work reported here relates particularly to recent investigations by the Technological Unit and by industry of the quality of once- and twice-frozen cod (*Gadus morhua*), flounder (*Hippoglossoides platessoides*) and redfish (*Sebastes marinus mentella*) with emphasis on *pre-rigor* handling and on the use of sodium tripolyphosphate (TPP) for treating fillets of thawed fish prior to second freezing. The authors are very pleased to acknowledge the valuable assistance received from industry in the prosecution of these studies. Use was made of freezer trawlers and of the production from commercial freezing, thawing and processing plants. There was considerable exchange of data for study purposes, particularly those dealing with results obtained from industry and laboratory taste panels. This co-operation has permitted drawing meaningful conclusions from the work.

METHODS

Laboratory procedures

Where applicable these followed the description given by the authors in a separate publication (MacCallum *et al.*, 1968).

In addition, thiobarbituric acid (TBA) values for rancidity were estimated using the distillation method described by Tarladgis *et al.* (1960). Values were expressed in optical density units read on a Coleman Jr. Spectrophotometer at a 540 mμ setting.

Peroxide values were determined according to Dyer and Morton (1956) with slight modifications and expressed as milliequivalents per 100 g fat. Titrations were done using a starch indicator, rather than making potentiometric titrations as in the original method.

Handling

In general, methods followed the description given by the authors in a separate publication (MacCallum *et al.*, 1968).

Fillets treated commercially with sodium tripolyphosphate (TPP) solution were brought into contact with the solution in a rotating drum. 7 and 2½ lb (3·2 and 1·2 kg) of 10.7 per cent TPP solution respectively were used for every 100 lb (45 kg) of cod and flounder fillets.

RESULTS AND DISCUSSION

Cod

Assessments indicating quality at killing and after cold storage. Earlier work (MacCallum *et al.*, 1966) showed considerable differences in the quality of Grand Bank cod at killing. These differences may have more influence on the quality of the frozen, stored fillet than handling and commercially-practised freezing and storage procedures.

Variation in texture, attributed for the most part to a variation in initial quality, is illustrated in table 1 which shows scores for frozen fillets prepared from representative commercial iced landings of Bank fish at St. John's. This is particularly well illustrated by the scores given cod frozen on 7th October 1964 and 19th October 1966, the respective values being 85 and 58. It is interesting too that other fish iced 24 h and once-frozen at sea on 10th October 1964 graded 66, as shown in italics, table 1, putting that particular catch in the same quality category with the 19th October 1966 lot and not with the 7th October 1964 landing.

TABLE 1. AVERAGE OVERALL TEXTURE SCORES*† GIVEN SHORE-PROCESSED‡ ONCE-FROZEN FILLETS OF ICED MARKET SIZE GRAND BANK COD LANDED BY COMMERCIAL TRAWLERS AT ST. JOHN'S

Date of landing	Post-mortem *age at freezing (days)*	*Overall texture (freshly frozen fish)*
1964 May 15	<7§	89±1.53 (23)
June 6	<8	81±1.54 (15)
June 15	<10	62±4.23 (19)
October 7	1	85±1.89 (17)
October 12	*1*	*66±2.20 (21)*
1965 March 18	4	76±3.08 (18)
April 13	<7	77±2.25 (23)
1966 March 7	4	74±0.57 (96)
May 3	5	65±3.93 (7)
June 11	<8	77±1.88 (16)
October 19	2	58±2.41 (16)

* Average scores are followed by the standard error of the mean and by the number of judgments (in parentheses).

† All taste tests were conducted within four weeks of freezing, storage in the interval being at −23°C (−10°F).

‡ Exception—landing made 12th October 1964 (results shown in italics). The handling of these fish, filleted and frozen at sea on 10th October 1964, is described by MacCallum *et al.*, 1966.

§ All *post-mortem* ages at freezing which could not be determined precisely are shown as less than the maximum *post-mortem* age of any of the vessels catch since the freshest samples (as judged by organoleptic examination) were selected for freezing.

There was significant variation in the quality of whole eviscerated headed cod frozen *pre-rigor* aboard commercial freezing vessels within 2 h of capture, the variation amounting to 8 to 11 points (table 2, November and February samples) in texture rating depending upon the block selected for examination. Muscle glycogen at killing these fish was low, 0.095±0.021 per cent (10) for the November catch and 0.057±0.021 per cent (10) for the 3rd February catch, suggesting the depletion of glycogen during the struggle involved in catching. With these once-frozen *pre-rigor* fish to which we would look for highest quality, there is no evidence of exceptional texture scores during cold storage, yet the overall texture is somewhat better than reported for frozen stored fillets of iced trawler landings (Dyer and Dingle, 1961). Of the present samples, those of January 1965 dropped 16 texture points in 28 weeks, one lot of the November 1965 catch 11 points in 39 weeks, while a second lot only four points in the same time, not a significant difference.

Table 3 shows the muscle glycogen at killing and 14 weeks after capture (following either freezing or refreezing) and the lactate 14 weeks after capture for fish selected

TABLE 2. AVERAGE OVERALL TEXTURE SCORES* AND CHEMICAL ASSESSMENT DURING STORAGE AT −23°C (−10°F) OF INCOMPLETELY PROCESSED BLOCK-FROZEN GRAND BANK COD (MARKET SIZE) LANDED BY COMMERCIAL FREEZER TRAWLERS AND OF PROCESSED REFROZEN FILLETS

		Once-frozen headed eviscerated cod or skin-on fillets								*Double-frozen fillets*				
Date of catching	*Preparation at sea*	*Muscle glyc. at killing (mg%)*	*Period in cold storage at tasting (weeks)*	*Overall texture*	*Thaw drip*	*Lactate (mg%)*	*Glyc. (mg%)*	*Post-mortem age at thawing (weeks)*	*Thawing medium used*	*Total cold storage at tasting (weeks)*	*Overall texture*	*Thaw drip*	*Lactate (mg%)*	*Glyc. (mg%)*
25th January 1965	Unskinned fillets frozen in 27-kg block	—	12	68±2.44 (21)	7.5†	—	—	12	Humidified air at 20°C	12	68±3.02 (21)	9.8¶	—	—
			40	52±2.28 (21)	2.3‡	—	—			40	42±2.41 (21)	6.0¶	—	—
29th November 1965	Dressed frozen in 45-kg blocks	95±20.6 (10)	B1.1 6	70±1.66 (22)	1.0§	382‡	23‡	3	Tap water at 13–15°C	6	59±1.74 (24)	13.8¶	257††	47††
			B1.1 45	59±2.05 (21)	1.0§	348†	17§			45	55±2.35 (20)	6.3††	488‡‡	28††
			B1.2 6	67±1.91 (21)	12.2§	234‡	4‡			6	63±1.12 (22)	11.3¶	191††	9††
			B1.2 45	63±1.90 (19)	0.8§	432†	4§			45	50±3.07 (21)	9.2††	452‡‡	7††
3rd February 1966	Dressed frozen in 45-kg blocks	57±20.9 (10)	B1.1 14	78±1.82 (25)	—	209†	14‖	8	Tap water at 13–15°C	14	69±1.05 (65)	12.0**	201‡‡	15‡‡
			B1.1 56	—	—	—	—			56	53±1.49 (17)	8.9**	—	8**
			B1.2 14	70±2.28 (23)	—	—	8†			14	67±1.52 (34)	10.0**	228‡‡	13‡‡
			B1.2 56	—	—	—	—			56	54±2.17 (18)	6.2**	—	14**

* Average scores are followed by the standard error of the mean and by the number of judgments (in parentheses).
† Three random samples from the block, results averaged.
‡ Two random samples from the block, results averaged.
§ Single random sampling from the block, single determination.
‖ Four random samples from the block, results averaged.
¶ Duplicate random samplings from each of two 1-lb (454-g) packages of several fillets, results averaged.
** Duplicate random sampling from one 1-lb (454-g) package of several fillets, results averaged.
†† Single random sampling from each of three 1-lb (454-g) packages of several fillets, results averaged.
‡‡ Single random sampling from each of four 1-lb (454-g) packages of several fillets, results averaged.

TABLE 3. MUSCLE GLYCOGEN, LACTATE, pH AND OVERALL TEXTURES SCORES* FOR INDIVIDUAL GRAND BANK COD CAUGHT 3RD FEBRUARY 1966, EVISCERATED AND BLOCK FROZEN (HEADS ON) WITHIN TWO HOURS OF CAPTURE

		At killing		*After 14 weeks cold storage at −23°C (−10°F)*					
Sample	*Length heads on (cm)*	*pH†*	*Glycogen‡ (mg%)*	*Once-frozen eviscerated fish§*		*Fillets refrozen eight weeks after capture*			*Overall texture scores*
				Glycogen (mg%)	*Lactate (mg%)*	*pH*	*Glycogen (mg%)*	*Lactate (mg%)*	
1	51	6.6	39	11	205				
2	51	6.9	37	—	198				
3	56	6.6	61	18	224				
4	49	6.8	157			6.51‖	15‖	275‖	65.9±2.28 (17)
5	51	6.8	37			6.52¶	14¶	196¶	65.0±2.67 (8)
6	56	6.9	8			6.82¶	10¶	131¶	72.2±2.55 (9)
	Averages		56.5	15	209		13	201	

* Average scores are followed by the standard error of the mean and by the number of judgments (in parentheses).
† A single pH reading on each sample.
‡ A single sample from each fish taken just ventral to the posterior end of the first dorsal fin.
§ A single random sample from each of the fish (samples 1 to 3) examined at killing.
‖ A single random sample from each of two 1-lb (454-g) packages, each package containing a portion of the fillets from the same fish (sample 4), results averaged.
¶ A single random sample from one 1-lb (454-g) package containing fillets from a single fish (samples 5 to 6).

at random from the single 3rd February haul. Three fish (samples 1 to 3) were examined at killing and again after 14 weeks storage (after single freezing) as heads-on gutted fish. Three other fish (samples 4 to 6) were examined at killing and again after six weeks refrozen storage (14 weeks after capture). In all three instances the pH of the latter samples in refrozen storage was lower than prior to first freezing. Texture scores were similar and low (at about 65) for pH readings of 6.51 and 6.52 respectively. The average score, 72, given the fish having a pH of 6.82 and lowest lactate content (131 mg per cent) was considerably higher. In general, however, lactates are similar in these once- and twice-frozen *pre-rigor* fish. In contrast to glycogen reserves in trap fish, those in the cod removed from the otter trawl after vigorous struggling are well depleted. On the assumption that ATP levels were likewise depleted we would not look for much retardation [in work with once-frozen (*pre-rigor*) trap fish (MacCallum *et al.*, 1968) high ATP levels at tasting correlated well with the ability of the fish to maintain its "as killed" low toughness rating in cold storage] in the rate of subsequent textural changes and as reported above, this in fact, was the situation.

Cold storage quality following double freezing and storage of pre-rigor cod. The textural qualities of twice-frozen fillets prepared from the same blocks of whole dressed or rough filleted *pre-rigor* frozen fish examined above (after single freezing) are also reported in Table 2. The samples were prepared after thawing the whole fish in tap water at 13° to 15°C (55° to 59°F) in 4½ h and the unskinned fillets in humidified air at 20°C (68°F) in 4½ h.

The fish of three (25th January catch and the second blocks of the 3rd February and 29th November catches) of the five blocks maintained quality immediately after refreezing. Fillets from the first block of the November catch showed a significant drop in texture immediately after thawing and refreezing but changed slowly during subsequent storage. Immediately after refreezing, the fillets from the second November block were only slightly

poorer than the once-frozen controls but the fish depreciated somewhat more rapidly during subsequent storage than did those of the companion November block. Initially, refrozen fillets from the first block of the February catch were very significantly poorer than the once-frozen controls, yet the former depreciated significantly after further storage. The quality of the November and February samples dropped more slowly during refrozen storage than did the January samples, perhaps because the latter were frozen first as fillets, rather than as whole fish. The texture of the January samples was barely acceptable after refrozen storage for 28 weeks at −23°C (−10°F). Of those samples of record, texture in the twice-frozen fillets after extended frozen storage was four (November, first block), 10 (January) and 13 (November, second block) points poorer than that for the respective once-frozen controls. The results show that *pre-rigor* freezing at sea and thawing ashore can be depended upon to yield acceptable or better refrozen quality up to about one year under the storage conditions described, but the fish will be slightly poorer than the once-frozen counterparts.

In earlier work on thawing, notice was taken of slight "cardboardy" odours present in fillets of thawed (in chlorinated fresh water) *pre-rigor* frozen cod. Upon inspection by experts in fish spoilage it was decided to determine the level of rancidity, the development of which might be accentuated in the absence of bacterial spoilage. C. H. Castell (personal communication) remarked on the possibility of rancid flavours developing in the absence of bacterial activity, as in these freshly-frozen fish, and expressed the view that if fish can be refrozen before oxidation in the fatty tissue reaches the accelerated stage there is little likelihood that it will develop in refrozen storage. Thus, we set about to determine the practical significance of the level of rancidity developed in the unwrapped once-frozen blocks prior to thawing and in wrapped fillets in refrozen storage. Investigation showed that rancidity (as determined by the TBA test) at any stage in handling once- or twice-frozen fish was of doubtful importance. To illustrate, separate examinations were made of once-frozen, skin-on fillets on the exterior and in the interior of the same unwrapped fillet block (25th January catch) referred to in table 2. In the once-frozen samples examined after three months' storage the TBA value for exterior fillets was 0.023 ± 0.005 ($n=4$) and for interior, 0.017 ± 0.003 ($n=4$). The taste panel scores at three months were: texture once-frozen fillets 68 ± 2.44 (20) and for refrozen skinned fillets prepared at this time after humidified air thawing at 20°C, 68 ± 3.02 (21); taste scores 68 ± 2.58 (20) and 66 ± 3.48 (21) for the once- and twice-frozen samples respectively. The panelists could not detect rancidity at this time or six months later when scores for both once- and twice-frozen fish were rather poor [once-frozen: texture 52.3 ± 2.28 (27), taste 51.5 ± 2.70 (27); twice-frozen: texture 41.9 ± 2.41 (27), taste 43.8 ± 2.56 (27)], the low grades for taste at nine months being attributed to staleness. At this time the TBA value for all once-frozen skin-on fillets, regardless of position in the remaining portion of the original block of rough fillets, was 0.028 ± 0.002 ($n=3$) and in the refrozen fillets, 0.038 ± 0.002 ($n=4$). Subsequent chemical and organoleptic examination of the effects of storing water-thawed cod (for handling and processing (MacCallum and Idler, 1967)) in ice at 0°C (32°F) for 20 h prior to processing and refreezing also showed no rancidity (TBA value 0.026 ± 0.0, $n=2$) after nine months refrozen storage.

Off-whiteness (tending to a green hue), characteristic of some fillets prepared from headed, gutted material thawed after *pre-rigor* freezing at sea, was not responsible for downgrading the twice-frozen stored packs examined above and in previous studies (MacCallum *et al.*, 1966, 1967; Peters *et al.*, 1968). Industry is not conscious of any difference in the acceptability of these refrozen fillets and blocks and the once-frozen pack produced from iced fish.

The other characteristic of these *pre-rigor* frozen Bank fish worthy of note is thaw-drip. Values for twice-frozen fish (table 2) in general are about the same as reported previously for very good quality twice-frozen fall fish (MacCallum *et al.*, 1964) and mostly within the range (4.3 to 13 per cent) reported by Dyer *et al.* (1964) for once-frozen fillets of iced offshore cod. The values reported for samples removed from once-frozen unfilleted fish are in general low, of the same order reported by Hartshorne and Puncochar (1951) and probably not indicative of the amounts expected in fillets frozen at sea before *rigor*.

Effects on refrozen storage quality of TPP treatment of thawed fillets of pre-rigor fish. A comparison between treated and untreated samples from the same *pre-rigor* frozen blocks (3rd February samples, see pp. 57 and 58) is available (table 4). The untreated fish graded 7 to 8 points lower in texture six weeks after refreezing and 9 to 13 points lower 48 weeks after refreezing, all differences being statistically significant. The twice-frozen TPP-treated fish compared very favourably with once-frozen untreated whole fish from the same blocks, texture scores for the former being 76 and 75 (table 4) 14 weeks after capture versus 78 and 70 (table 2) for the once-frozen. Six weeks after refreezing the thaw-drip for the twice-frozen treated samples was considerably lower than that for the untreated (table 4, 3.2 and 3.4 per cent versus 12.0 and 10.0 per cent). However, there was little difference in drip resulting from TPP treatment in samples stored an additional 42 weeks (table 4). The pH of the treated samples averaged 6.90 at 14 weeks compared with 6.54 for the untreated samples. At 56 weeks the pH was 6.96 and 6.52 respectively.

It is suggested that the improved texture in twice-frozen TPP-treated cod could be the result of exposure of greater surface area of the fillet to the solution during dipping (because of a weakening of flesh consistency due to thawing) than would be the case in treating fillets of fresh chilled but unfrozen fish. It has already been suggested (Love and Abel, 1966) that any such improvement in texture in TPP-treated fish is possibly related to the partial extraction of the tissue at the surface which would then become softer in consistency.

Other results (table 4) are available for treated twice-frozen lots prepared after dielectric thawing for 1¼ h (30th November catch) and after water thawing at 13°C (55°F) for 4½ h (27th February catch). Texture assessment of the 30th November lot up to 42 weeks was made by

TABLE 4. OVERALL TEXTURE SCORES* AND THAW-DRIP FOR TPP-TREATED AND UNTREATED TWICE-FROZEN FILLETS OF GRAND BANK MARKET SIZE COD FROZEN INITIALLY IN 45 KG (100 LB) BLOCKS WITHIN TWO HOURS OF CAPTURE

Date of catch	Handling ashore	Post-mortem age at thawing (weeks)		Total cold storage at tasting (weeks)	Overall texture and thaw-drip: Untreated: Texture score	Untreated: Thaw-drip† (% wet wt)	Treated: Texture	Treated: Score	Treated: Thaw-drip† (% wet wt)
30th Nov. 1964	Blocks conveyed through a six-generator, 120-kW commercial thawer operating at 38 Mc/s frequency in about 1¼ h, filleted, packed and refrozen		2	2	—	—	75 —	(17)	—
				7	—	—	63 —	(22)	—
				14	—	—	62 —	(17)	—
				21	—	—	61 —	(22)	—
				31	—	—	65 —	(14)	—
				42	—	—	60 —	(23)	—
				43	—	—	67±2.27	(26)	—
				58	—	—	70±1.64	(23)	—
27th Feb. 1965	Blocks thawed in tap water at 13°C (56°F) for 4¼ h, filleted, packed and refrozen		3	8	—	—	74±2.65	(21)	—
				30	—	—	62±1.68	(34)	—
				44	—	—	70±1.97	(23)	—
3rd Feb. 1966		B1.1	8	14	69±1.05 (65)	12.0	76±1.79	(31)	3.2
				56	53±1.49 (17)	8.9	66±1.51	(18)	7.1
		B1.2	8	14	67±1.52 (34)	10.0	75±1.92	(33)	3.4
				56	54±2.17 (18)	6.2	63±1.67	(17)	5.0

* Average scores are followed by the standard error of the mean and by the number of judgments (in parentheses). The standard errors for the first six samples (30th Nov.), assessed by the industry panel, are not available.
† Duplicate random samples from each of two 1-lb (454-g) packages, results averaged.

a panel of plant personnel following directions from the laboratory. The last two texture assessments were made on this pack in the Technological Unit laboratory at 43 and 58 weeks. It is evident that after about one year's storage there was only a slight drop in quality. Again the twice-frozen treated fish prepared from the 27th February lot (table 4) were quite good after nearly one year's storage, scoring 70.

Thus, the refrozen storage quality of *pre-rigor* frozen cod tends to hold up very well with TPP treatment before second freezing, being comparable to that of once-frozen untreated fish.

In closing our remarks on cod we must comment on the taste sensations experienced by the panelists offered a TPP-treated sample. The panelist is required to record changes in flavours independent of considerations of the overriding sweety-salt taste imposed by the TPP. The laboratory panel tended to taste-grade the twice-frozen 30th November samples held for a year at about 60 with emphasis on the absence of sea-fresh tang while the industry panel almost unanimously graded them 10 points higher.

Bank-caught flounder

Chemical assessment. Results of an initial study of cold storage quality for once- and twice-frozen flounder are reported in table 5, these being fairly similar for once- and twice-frozen stored samples and for *pre-* and *in-rigor* material. Freezing methods were similar to those described for October cod (MacCallum *et al.*, 1966). The fish were first frozen on 8th and 9th October 1964 on the Grand Bank before and during *rigor*. Packaged skinned fillets, wrapped in Saran, were stored aboard and ashore at −23°C (−10°F) while block-frozen gutted whole fish,

TABLE 5. CHEMICAL ASSESSMENT OF ONCE- AND TWICE-FROZEN FILLETS OF GRAND BANK FLOUNDER* CAUGHT 8TH OCTOBER 1964

Sample†	Weeks in cold storage after capture	Moisture‡ (% wet wt)	Thaw-drip‡ (% wet wt)	T.L.§ (% wet wt)	FFA§ (% T.L.)	Peroxide§ (mEq/100 g fat)	TBA‖ (O.D. units)	EPN‡ (% wet wt)
(1)	6	81.3	10.2	1.95	9.5	0.07	0.054	2.00
(2)		83.2	13.9	1.86	9.1	0.27	0.042	1.70
(3)		—	—	—	—	—	—	—
(4)		—	—	—	—	—	—	—
(1)	10	81.0	7.9	1.37	15.6	1.62	0.043	1.92
(2)		81.9	14.5	1.30	16.4	0.37	0.074	1.83
(3)		82.6	18.2	1.05	20.0	1.08	0.013	1.88
(4)		80.0	11.8	1.20	20.3	0.32	0.020	2.16
(1)	22	83.0	11.9	1.45	16.8	0.51	0.044	1.50
(2)		81.8	19.4	1.23	17.7	1.01	0.073	1.62
(3)		80.8	15.2	1.21	22.6	1.44	0.023	1.99
(4)		81.3	20.5	1.40	17.6	1.32	0.010	1.95
(1)	34	81.4	17.8	2.55	17.1	8.57	0.246	1.66
(2)		83.7	26.5	1.32	24.8	6.40	0.069	1.53
(3)		81.4	14.0	2.46	20.6	2.71	0.048	2.02
(4)		81.9	11.5	1.31	28.4	4.18	0.044	2.08

* Average weight of fish was 1.35 kg.
† Frozen once (1) before *rigor*, (2) *in-rigor*. Frozen twice [first freezing (3) before *rigor*; (4) *in-rigor*] 10 weeks after capture.
‡ Duplicate samples from each of two 12-oz (340-g) packages of several fillets, results averaged.
§ Single samples from each of two 12-oz (340-g) packages of several fillets, results averaged.
‖ Duplicate readings of single random sampling from two 12-oz (340-g) packages of several fillets.

stored aboard at the same temperature, were thawed ashore in tap water at 15.5°C (60°F) in 3½ h (10 weeks following capture), processed, packed in the same fashion as the controls, frozen and stored at −23°C.

The moisture content varied from 81.0 to 83.0 (*pre-rigor* controls) and from 81.8 to 83.7 (*in-rigor* controls) and in twice-frozen fish from 80.8 to 82.6 (*pre-rigor*, first freezing) and 80.0 to 81.9 (*in-rigor*, first freezing). The thaw-drip ranged from 7.9 to 17.8 per cent (*pre-rigor*, once-frozen) and from 13.9 to 26.5 per cent (*in-rigor*, once-frozen); and in the twice-frozen from 14.0 to 18.2 per cent (*pre-rigor*, first freezing) and from 11.5 to 20.5 per cent (*in-rigor*, first freezing). There is no evidence that the amount of drip was affected by double freezing the *in-rigor* fish. The lower figure of the range in drip values for samples initially frozen before *rigor* was raised as the result of double freezing. Where samples were frozen only once, thaw-drip values were increased by over 50 per cent as the result of freezing during *rigor*. The *in-rigor* prepared, once-frozen fillets examined at 34 weeks developed 26.5 per cent thaw-drip, the highest recorded, and possessed the highest moisture, 83.7 per cent. Total lipid varied with fish and not with treatment, values ranging from 1.1 to 2.6 per cent, compared with values of 1.1 to 1.9 per cent reported by Dyer and Morton (1956). FFA values ranged from 9 to 25 per cent T.L. for once-frozen and from 18 to 28 per cent T.L. for twice-frozen, compared with values of 30 to 40 per cent found by Dyer and Morton (1956) for once-frozen flounder stored at −12°C (10°F). Peroxide values varied from 0 to 2 milliequivalents per 100 g fat during the first 22 weeks' storage and thereafter increased, at 34 weeks the values for the twice-frozen being lower than those for the once-frozen. TBA values were generally low and steady throughout the storage period except for the *pre-rigor* control samples at 34 weeks. As in the case of peroxide values, TBA values were lower in the twice-frozen samples. Extractable protein was usually 1.6 to 2.0 per cent with four exceptions; the twice-frozen being equal or slightly better than the once-frozen.

Cold storage quality following double freezing of pre-rigor flounder. Further work correlated chemical and organoleptic assessment of twice-frozen flounder. Fish were frozen *pre-rigor* in 100-lb (45-kg) blocks on the Grand Bank in July 1966, stored at −23°C (−10°F) for one month then conveyed in 1¼ h through a six-generator, 120-kW commercial thawer operating at a frequency of 38 Mc/s under reduced power. The fish which were completely thawed were filleted and skinned. Of the fillets produced, those having the white appearance of fillets of iced trawler fish were segregated from those of darker, greenish hue. The two lots were treated with TPP, packed in 1-lb (454-g) cartons, overwrapped in Saran, refrozen immediately, cold stored and examined six and 26 weeks after refreezing. Results of chemical assessment (table 6) are very similar to those reported in table 5 for the 1964 twice-frozen flounder. The present refrozen samples yielded slightly less drip a few weeks after refreezing than did the untreated twice-frozen flounder (table 5). The off-white fillets (table 6) had higher T.L. than the white fillets but FFA expressed as percentage T.L. was considerably less, making the total FFA about equal on a weight basis. It should be noted that more recent work (unpublished) shows no correlation of fat content and colour. In the samples reported (table 6) there was a difference in TBA as between white and off-white fillets after 30 weeks' storage. There was a significant difference after cold storage in the taste of the off-white and white fillets, the former being reduced to a score of 32, 30 weeks after capture, compared to 50 for the white-coloured fillets (table 7). Later results (MacCallum and Idler, 1967) failed to confirm this finding. The panel tended to find great difficulty in assessing the flounder for taste in the presence of the flavour imparted by the sodium tripolyphosphate. As a result, scores for taste may be somewhat low in terms of actual quality. The results indicate the need for future research.

Table 7 lists the texture scores of the TPP-treated twice-frozen stored samples referred to above along with scores for a number of lots of once-frozen fillets prepared from iced landings. The quality of the former was on a par with four-day iced fish caught and once-frozen during the same season, but somewhat poorer than other once-frozen lots obtained at other seasons. Notwithstanding, the twice-frozen summer fish were still of above acceptable texture 30 weeks following capture. The twice-frozen fish prepared from white-coloured fillets was at least

TABLE 6. CHEMICAL ASSESSMENT DURING REFROZEN STORAGE OF WHITE AND OFF-WHITE FILLETS OF FLOUNDER PROCESSED, TPP-TREATED AND REFROZEN 11TH AUGUST 1966 AFTER DIELECTRIC THAWING (IN WATER IN PLASTIC TRAYS). THE ORIGINAL BLOCKS OF EVISCERATED FISH WERE FROZEN AT SEA WITHIN TWO HOURS OF CAPTURE (JULY 1966)

	White fillets		*Off-white fillets*		*Notes*
Period of cold storage as once-frozen blocks (weeks)	4		4		
Total cold storage time at assessing (weeks)	10	30	10	30	
Moisture (per cent wet weight)	81.7	81.2	81.4	80.9	Duplicate random sampling of one 1 lb package of several fillets, results averaged
Thaw-drip (per cent wet weight)	10.8	12.7	9.9	14.1	
T.L. (per cent wet weight)	0.88	1.16	1.38	2.43	Single random sampling of each of 2 lb packed as above, analysed separately and averaged
FFA (per cent T.L.)	20.7	22.1	17.1	12.1	
TBA (O.D. units)	0.017	0.037	0.025	0.088	Duplicate readings of single random sampling of 1 lb packed as above
EPN (per cent wet weight)	1.89[a]	1.74[b]	1.87[a]	1.79[b]	(a) Separate analyses of duplicate samples from each of 2 lb packed as above, results averaged (b) Separate analyses of single sample from each of 2 lb packed as above, results averaged

TABLE 7. OVERALL TEXTURE AND TASTE SCORES* FOR ONCE-FROZEN FLOUNDER FILLETS OF ICED LANDINGS WITH OR WITHOUT TPP TREATMENT AND FOR REFROZEN WHITE AND OFF-WHITE TPP-TREATED FILLETS FROM BLOCKS FROZEN *PRE-RIGOR* AT SEA

Date of capture (1966)	*Handling at sea*	Post-mortem *age at freezing*	*Handling ashore*	*TPP treated*	*Appearance of fillets*	*Total weeks in cold storage at tasting*	*Texture*	*Taste*
14th Mar.	Iced	2 days	Filleted, skinned, packed in 1 lb cartons, frozen and cold stored	No	White	26	70±3.00 (16)	55±4.64 (16)
						46	63±1.42 (18)	31±1.70 (18)
14th Mar.	Iced	2 days		Yes	White	26	73±2.35 (16)	71±3.37 (16)
						46	81±1.17 (18)	47±4.18 (18)
29th June	Iced	4 h		Yes	White	12	76±2.75 (16)	74±2.83 (16)
29th June	Iced	4 h		No	White	12	77±3.95 (15)	73±4.88 (15)
						32	68±2.53 (18)	44±2.47 (18)
29th Aug.	Iced	4 days		Yes	White	4	68±1.77 (23)	72±2.10 (23)
						24	55±2.77 (18)	36±2.20 (18)
15th July	Frozen in 45 kg blocks of eviscerated fish	0–2 h	Filleted, skinned and refrozen after dielectric thawing (at reduced power) 1 month *post-mortem*	Yes	White	10	62±2.78 (23)	62±2.72 (23)
						30	56±3.18 (18)	50±2.96 (18)
15th July		0–2 h		Yes	Off-white	10	63±2.22 (23)	60±3.49 (23)
						30	64±1.44 (18)	32±3.16 (18)

* Average scores are followed by the standard error of the mean and by the number of judgments (in parentheses).

equal in taste to all once-frozen samples after extended storage. Twice-frozen fish prepared from the off-white fillets was given a taste score very similar to two of the once-frozen lots, being inferior to two other samples.

Other samples, *pre-rigor* at first freezing on the Bank (December 1964) were dielectrically thawed (in 1¼ h) 10 days later, processed, packed without TPP treatment and refrozen. Fish from the same catch iced for 2½ days were once-frozen. All samples were given similar texture ratings up to nine weeks' storage (score of 72) but thereafter (at 15, 22 and 30 weeks) the once-frozen material graded 10 points higher than the twice-frozen, the latter remaining constant at close to 60 during all the later periods. After nine weeks' storage the industry panel judged the once-frozen samples to be considerably more "sea fresh" than the twice-frozen. Nevertheless, all samples were graded quite high for taste, the control being given a score of 85 and the twice-frozen 75 after 30 weeks.

All evidence therefore points to the fact that *pre-rigor* freezing flounder at sea, thawing ashore and processing will yield a very satisfactory refrozen pack.

Effect of TPP treatment of once-frozen flounder. There is conflicting evidence of improvement in textural qualities of flounder with TPP treatment. There was no difference in the texture of treated and untreated samples prepared in March 1966 and stored 26 weeks, but considerable difference in flavour of the treated sample after an additional 20 weeks' storage (table 7). There was no difference between treated and untreated 29th June shore fish held 12 weeks. The small amount of TPP solution used commercially (practice followed in the samples reported in table 7), in relation to treatment of cod, could account for the absence of clear differences in quality of treated and untreated flounder fillets.

Cold storage quality following double freezing of pre-rigor redfish

MacCallum *et al.* (1967) previously reported the results of organoleptic and chemical assessment of once- and twice-frozen redfish. Further work, based solely on organoleptic assessment, carried was out by industry. The quality of the lot of fish described below is typical of industry's pack. The results confirm the opinion expressed in the published report that twice-frozen redfish are at least equal in frozen storage to once-frozen material prepared aboard ship and indicate too that the twice-frozen material is equal in quality to that of once-frozen fish prepared from iced trawler landings.

Whole ungutted redfish were frozen *pre-rigor* in 4-in thick blocks aboard ship in December 1964, thawed dielectrically in 1¼ h by industry personnel (see above) within 10 days of freezing, filleted, packed skins-on in 1-lb (454-g) cartons without TPP treatment, frozen in 1 h and stored at −23°C (−10°F). Nine weeks later other fish, landed in ice 2½ days following capture, were filleted, frozen skins-on and used as controls. Nine, 15, 22 and 30 weeks from capture of the sea-frozen fish the industry panel graded once- and twice-frozen samples similarly for texture, values dropping little (from 68 to 61) in this interval. This grade is slightly lower than previously reported (MacCallum *et al.*, 1967). Taste grades for the once- and twice-frozen samples were similar also, being 78 at nine weeks and dropping to 65 at 30 weeks because of the development of "oily" tastes. These values too are slightly lower than reported previously (MacCallum *et al.*, 1967).

Acknowledgments

The authors gratefully acknowledge the co-operation of Mr. A. H. Monroe, President, Fishery Products Ltd., St. John's, Newfoundland, who made it possible to extend our research into actual fields of operation. They wish to thank Messrs. G. C. Shea, J. S. Crewe, Fletcher Mayo and James Clarke of Fishery Products Ltd. and Messrs. J. T. Lauder and E. E. Coldwell of the Technological Unit staff for technical assistance in the preparation of some of the samples at sea and ashore. The following persons contributed to both laboratory and taste panel phases of the work: Mrs. Coty L. Otsuka, Mrs. Rosamund Gover and Mr. Bevin LeDrew; the following to laboratory work in particular: Messrs. David R. Adams and George J. Biggs, and Misses Joan M. Murphy and Teresita Tan. Mr. Fletcher Mayo was in charge of the industry taste panel.

References

BANKS, A Identifying quality changes in frozen fish. *Annex* 1962 1962–1 *Bull. int. Inst. Refrig.*, 445–451.

BORGSTRÖM, G The Atlantic fisheries of the U.S.S.R. In 1961 *Atlantic Ocean Fisheries*, ed. G. Borgström and A. J. Heighway, Fishing News (Books) Ltd., London, pp. 282–315.

DYER, W J and DINGLE, J R Fish proteins with special 1961 reference to freezing. In *Fish as Food*, ed. G. Borgström, Academic Press, New York, **1**, 275–327.

DYER, W J and MORTON, MARGARET Storage of frozen plaice 1956 fillets. *J. Fish. Res. Bd Can.*, **13**, 129–134.

DYER, W J, BROCKERHOFF, H, HOYLE, R J and FRASER, 1964 DORIS I Polyphosphate treatment of frozen cod. I. Protein extractability and lipid hydrolysis. *Ibid.*, **21**, 101–106.

HARTSHORNE, J C and PUNCOCHAR, J F Studies on round 1951 fish frozen at sea—New England species. *Fd Technol., Champaign*, **5**, 492–495.

JONES, N R Freezing fillets at sea. In *Fish Quality at Sea*, 1965 World Fishing and White Fish Authority, London, pp. 81–88.

LOVE, R M and ABEL, G. The effect of phosphate solutions on 1966 the denaturation of frozen cod muscle. *J. Fd Technol.*, **1**, 323–333.

MACCALLUM, W A and IDLER, D R Influence of thawing and 1967 thawing methods on the immediate and refrozen storage quality of fish. FAO Technical Conference on the Freezing and Irradiation of Fish, 4–8th September, Madrid.

MACCALLUM, W A, SHIOH, H S, CHALKER, DOROTHY A, 1964 DYER, W J and IDLER, D R Polyphosphate treatment of frozen cod. 2. Effect on drip, yield, lipid hydrolysis and protein extractability in twice-frozen Newfoundland summer trap and fall cod. *J. Fish. Res. Bd Can.*, **21**, 539–548.

MACCALLUM, W A, LAISHLEY, E J, DYER, W J and IDLER, D R 1966 Taste panel assessment of cod fillets after single and double freezing. *Ibid.*, **23**, 1063–1081.

MACCALLUM, W A, CHALKER, DOROTHY A, DYER, W J and 1967 IDLER, D R Effects of water and dielectric thawing processes on shelf life of double-frozen cod and redfish. *Ibid.*, **24**, 127–144.

MACCALLUM, W A, JAFFRAY, JUNE I, CHURCHILL, D N and 1968 IDLER, D R Condition of Newfoundland trap-caught cod and its influence on quality after single and double freezing. *Ibid.*, **25**(4), 733–755.

PETERS, J A and SLAVIN, J Freezing at sea. Complete report 1960 on the keeping qualities of trawler-frozen fish opens new possibilities in our production methods. *Fishg Gaz., N.Y.*, April, 77, 32–33, 66, 76, 78, 136.

PETERS, J A, MACCALLUM, W A, DYER, W J, IDLER, D R, 1968 SLAVIN, J W, LANE, J P, FRASER, D I and LAISHLEY, E J Effect of state of *rigor*, and of freezing-thawing processing on storage quality of refrozen cod. *J. Fish. Res. Bd Can.*, **25**(2), 299–320.

TARLADGIS, B G, WATTS, BETTY M, YOUNATHAN, MARGARET 1960 T and DUGAN, Jr, L A distillation method for the quantitative determination of malonaldehyde in rancid foods. *J. Am. Oil Chem. Soc.*, **37**, 44–48.

Discolouration in Sea-frozen Fish Fillets

by T. R. Kelly

Discolouration in sea-frozen fish fillets

One of the major criticisms of sea-frozen fish fillets is that they very often show marked brown staining, particularly at the cut surface, and although blood pigments have commonly been implicated, the factors which determine fillet colour have not been clearly established.

Tests have been recently carried out at sea on two commercially important species, cod (*Gadus morhua*) and redfish (*Sebastes marinus*), in which various methods of bleeding have been compared for their efficiency in producing fillets of an acceptable colour. It was found that when care is taken to remove blood completely from fish before filleting, by perfusing the muscle, via the blood system, with water, no discolouration is ever found. For the more conventional forms of bleeding, e.g. throat and tail cutting or simply gutting, the circulatory system should be cut as soon as possible after capture. Following this a storage period before filleting is necessary to produce a fillet which would be acceptable after freezing and thawing. The time of storage required depends on the species. Acceptable cod fillets were produced in less than two hours while redfish required at least four hours to produce the same quality of fillet. The differences in bleeding behaviour can be explained by observed differences in circulatory systems of the two fish.

Coloration des filets congelés de poisson de mer

L'une des principales critiques dont les filets de poisson de mer congelés font l'objet est qu'ils manifestent souvent des taches accentuées de brunissement, notamment sur les surfaces coupées et, bien que la responsabilité de ces taches ait été généralement imputée aux pigments du sang, les facteurs déterminant la couleur du filet n'ont pas été clairement déterminés jusqu'à présent.

Des essais ont été récemment effectués en mer sur deux espèces commerciales importantes, la morue (*Gadus morhua*) et la chèvre (*Sebastes marinus*), au cours desquels on a comparé différentes méthodes de saignage pour établir dans quelle mesure elles pouvaient donner lieu à des filets d'une couleur acceptable. On a constaté que lorsqu'on prend soin de vider complètement le poisson de son sang avant le filetage, par perfusion d'eau, aucune coloration ne se manifestait. Si l'on adopte les méthodes courantes de saignage, par tranchage la gorge et de la queue, ou par simple éviscération un gros voisseau sanguin devrait être sectionné aussitôt que possible après la capture. Une période d'entreposage avant le filetage est alors necessaire pour produire un filet acceptable après la congélation et la décongélation. La période d'entreposage nécessaire dépend de l'espèce. Des filets de morue acceptables on été produits en moins de deux heures; quant aux chèvres, il a fallu au moins quatre heures pour obtenir une qualité de filet analogue. Les différences de comportement au saignage peuvent être attribuées aux différences qu'on a observées entre le système circulatoire de deux espèces.

Cambio de color en los filetes de pescado marino congelado

Una de las principales objeciones que se hacen a los filetes de pescado marino congelado es que, con mucha frecuencia, muestran marcadas manchas oscuras, especialmente en la superficie del corte y aunque a veces sea debido a los pigmentos de la sangre, sin embargo no se ha establecido con claridad cuáles son los factores que determinan el color de los filetes.

Recientemente se han realizado pruebas en el mar con dos especies de importancia comercial, bacalao (*Gadus morhua*) y gallineta (*Sebastes marinus*), en las que se han comparado diversos métodos de desangrado para comprobar su eficacia y la producción de filetes de un color aceptable. Se comprobó que cuando se tiene cuidado de quitar completamente la sangre del pescado antes de filetearlo, mediante perfusión de agua en el tejido muscular, a través del sistema sanguíneo, no se producen cambios de color. Por lo que se refiere a las formas más corrientes de sangrado, como por ejemplo, corte del cuello y la cola, o simplemente eviscerando, el sistema circulatorio se deberá cortar lo más pronto posible después de la captura. A continuación es necesario un período de almacenamiento antes del corte en filetes, con objeto de obtener un producto que sea aceptable después de la congelación y la descongelación. El tiempo de almacenamiento necesario depende de la especie. Se produjeron filetes aceptables de bacalao en menos de dos horas, mientras que la gallineta exigió por lo menos cuatro horas para producir filetes de la misma calidad. Las diferencias en la forma de proceder durante el sangrado se pueden explicar por las que se observan en los sistemas circulatorios de los dos peces.

ONE of the major criticisms of sea-frozen fish fillets is that they very often show marked brown staining, particularly at the cut surface. It has commonly been accepted that much of the discolouration is due to the presence in the tissues of blood pigments which have not been efficiently removed before freezing. It has recently been shown (Kelly and Little, 1966) that the haemoglobins of marine fish autoxidize very readily compared with their mammalian counterparts to form a brown product. In the same paper a specific "*pre-rigor* cut surface" effect was described in which the cells which are ruptured at the cut surface exude their contents which then form a coagulum in and under which blood pigments may be trapped and protected from removal by washing with water.

The logical conclusion from the above work is that the removal of blood from the tissues should be carried out before the filleting stage if *pre-rigor* fillets are required. There is, however, little information on the factors which govern the ease of removal of blood from tissue. Jones (1964) observed that fillets cut from freshly-killed exhausted cod were much more discoloured than fillets cut from rested fish, but that holding a gutted cod for half an hour on ice before filleting allowed sufficient drainage of blood to give the fillets an acceptable colour. Partmann and Gutschmidt (1963) compared the colours of cod and redfish fillets cut in various stages of *rigor* and found that the colour of redfish fillets was in general less acceptable than that of cod. Only in the case of redfish did pre-treatment alter the colour of the flesh. He concluded that the colour of fillets could be related to the differing degree of blood drainage and that this was probably related to the time after death at which the gills were cut, and to the time between gill cutting and filleting.

The object of the work reported here was to compare a variety of bleeding procedures which might be adopted at sea with regard to their efficiency in producing fillets of an acceptable colour.

MATERIAL AND METHODS

Experimental fish

Two commercially important species of fish, cod (*Gadus morhua*) and redfish (*Sebastes marinus*) were studied. Experiments were carried out while fishing off the west coast of Greenland during the autumn of 1965.

Bleeding experiments

Several combinations of bleeding methods and storage conditions were investigated. These were:

(1) Fish were left whole and stored either in ice at 0°C (32°F) or in air at work deck temperature, up to 7°C (45°F).

(2) On arrival on the work deck, fish had their tails removed and were then stored as described above, or in running sea water, at 4°C (39°F).

(3) Fish were stored as above after having tails cut off and throats cut.

(4) Cod only were gutted in the normal way immediately after capture and stored as above.

(5) Blood in the circulatory system of the fish was washed out by inserting a syringe needle into the dorsal aorta and injecting sea water, after removing the head and tail.

For each experiment in this series 12 fish were taken from a trawl and treated and stored under one of the sets of conditions described above. At fixed intervals two fish were removed from the batch and filleted. The fillets, without washing, were then photographed under a standard set of conditions, placed in a polythene bag and frozen.

Assessment of colour of fillets

Colour slides. The assessment of the colour of fillets before freezing was made in the laboratory from colour slides. The scale on which the colour of the fillets was scored was an arbitrary one in which the best fillets were given a score of five and the worst a score of one. A colour panel of 12 people each gave a score to the colour slides by comparing them against two standards with scores of one and five. Separate standards were used for the cod and redfish slides.

Thawed samples. The frozen fillets prepared at sea were all brought back to the laboratory where they were thawed overnight and further assessed, visually for colour, again using an arbitrary five-point scale.

RESULTS

Experiments on cod

The results of the bleeding experiments on cod are shown in fig 1. The curves fall into three distinct groups; the whole fish, the fish bled by conventional methods and the mechanically-bled fish. As expected the fish stored whole before filleting always gave fillets whose colour was inferior to the rest. Nevertheless, since there is a gradual improvement in the colour with time it is probable that the tension produced within the muscle as *rigor* develops forces some of the blood which is present in the muscle at death back into the large blood vessels in the backbone. This may account for the fact that the 7°C (45°F) stored fish gave slightly better fillets than the 0°C (32°F) stored fish, since *rigor* would obviously be faster at the higher temperature.

Of the conventional methods of bleeding, throat and tail cutting or simple gutting, especially when combined with a sea-water wash, appear to be slightly more effective than tail cutting alone. Temperature of storage in the range 0° to 7°C (32° to 45°F) has little effect.

By far the best method of producing acceptable fillets is to remove the blood completely before filleting by perfusing the muscle via the circulatory system with sea water. This produces a very white fillet whose colour rating understandably cannot really improve with time. An interesting point with these fish is that the 7°C (45°F) stored fish scored slightly higher than the 0°C (32°F) stored fish. This was not due to differences in pigmentation in the fillets but to differences in translucency. The 7°C (45°F) stored fish were on the whole slightly more opaque, and they showed up in colour slides as being whiter.

Experiments on redfish

The results of the bleeding experiments on redfish are shown in fig 2. The pattern of fillet colour change with time is somewhat different to that for cod. The curves are on the whole less steep and there is not such a clear distinction between the curves for whole and conventionally-bled fish. The difference between tail cutting and throat and tail cutting was much more pronounced than was the case with cod and it is clear that the additional cut at the head of the fish is very beneficial.

Once more perfusion of the circulatory system with sea water was by far the best method of producing acceptable fillets and the slight difference between the 0°C (32°F) and 7°C (45°F) was again evident.

Examination of thawed fish

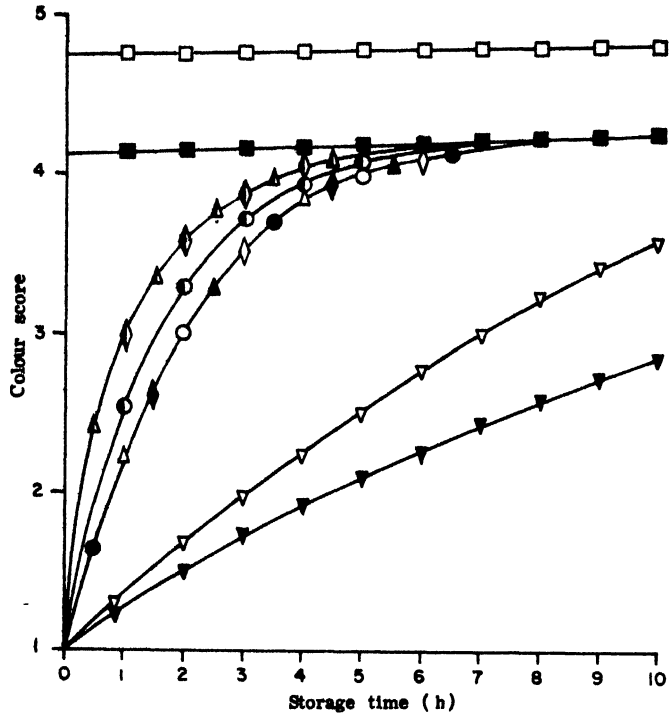
When the experimental fillets were thawed out in the laboratory and assessed for colour it was found that the colour gradings agreed with the gradings given to the colour slides although there was an overall slight improvement due principally to the increased opacity of frozen and thawed fish muscle. This was particularly noticeable in the mechanically-bled fillets where the differences due to temperature of storage noted before freezing were cancelled out in the thawed fillets.

DISCUSSION

If we set a colour score of three as being the limit of acceptability we can compare all of the bleeding methods and conditions of storage for both species of fish by comparing the time of storage required to give fillets this colour score. These times are shown in table 1.

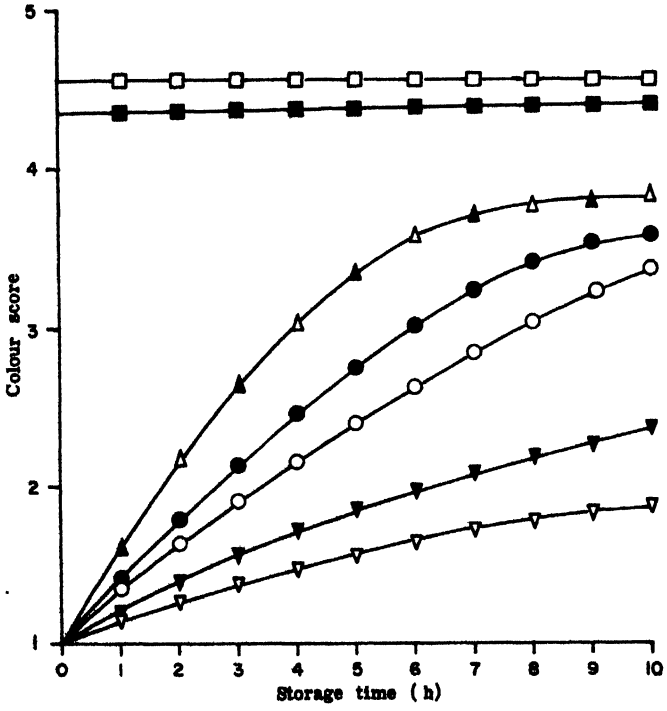
The most interesting fact which emerges from this table is that, where direct comparisons can be made, redfish consistently require longer storage under a standard set of conditions than cod, in order to produce acceptable fillets. Thus, when tail cutting is used redfish require to be stored three to four times as long as cod, and when both throat and tail cutting are employed they require twice as long as cod.

These results support the view that a larger percentage of the volume of the circulatory system is to be found in



Bleeding Method	Storage Conditions		
	Ice at 0° C (32° F)	Air at 7° C (45° F)	Sea water at 4° C (39° F)
Whole fish	▼	▽	
Tail cut	●	○	◐
Throat and tail cut	▲	△	▲
Gutted	◆	◇	◆
Sea water perfusion	■	□	

Fig 1. Relationship between colour score of cod fillets, bleeding method and storage time before filleting. The points shown are those of smoothed-out curves, not experimental points and are only used for identification



Bleeding Method	Storage Conditions	
	Ice at 0° C (32° F)	Air at 7° C (45° F)
Whole fish	▼	▽
Tail cut	●	○
Throat and tail cut	▲	△
Sea water perfusion	■	□

Fig 2. Relationship between colour score of redfish fillets, bleeding method and storage time before filleting. The points shown are those of smoothed-out curves, not experimental points and are only used for identification

TABLE 1. EFFECT OF BLEEDING METHODS AND STORAGE CONDITIONS ON TIME REQUIRED TO PRODUCE ACCEPTABLE COD AND REDFISH FILLETS

Bleeding method	*Storage conditions*	*Required storage time (h)*	
		Cod	*Redfish*
Whole fish	Air at 7°C	7	>24
	Ice at 0°C	14	18
Tails cut	Air at 7°C	2	8
	Ice at 0°C	2	6
	Running sea water	<2	—
Throats and tails cut	Air at 7°C	2	4
	Ice at 0°C	2	4
	Running sea water	1	—
Gutted	Air at 7°C	2	—
	Ice at 0°C	2	—
	Running sea water	1	—
Muscle perfused with sea water	Air at 7°C	0	0
	Ice at 0°C	0	0

Fig 3. Thawed fillets from bled and unbled redfish showing the cut surface and the lateral line muscle. Left: fillet cut from fish bled by infusion. Right: fillet cut from whole unbled fish

the muscle of redfish than is found in cod (Kelly and Little, 1966). Further evidence for this came from some observations made on the thawed fillets. It was found that the fillets which were badly discoloured at the cut surface also appeared to have very dark brown muscle on the skin side of the fillet. However, fillets cut from mechanically-bled fish had no cut surface discolouration and were only pale brown on the skin side. Fig 3 illustrates these observations. It had always been assumed previously that a very dark colour on the skin side of a redfish fillet was associated with a high proportion of myoglobin but since myoglobin is an intracellular pigment it should not be removed by perfusion of the blood system. Therefore any dark colour on the skin side must be associated with blood pigment, and hence there exists in a freshly-caught redfish a considerable reservoir of blood which is rather difficult to remove in normal bleeding procedures.

The storage times required to give acceptable fillets under the various conditions in table 1 cannot necessarily be equated with the minimum requirements which should be adopted in sea processing for two reasons. The arbitrary scale used for colour assessment only provides a means of comparing acceptabilities between treatments rather than an absolute acceptability. More important still is the fact that the fillets were not washed after cutting.

CONCLUSIONS

(1) All fish should have their circulatory systems cut as soon as possible after capture.

(2) Total removal of blood by perfusing the muscle in the circulatory system is by far the best method of bleeding but presents very large technical problems.

(3) For cod, simple gutting is as effective as any of the other methods of bleeding.

(4) Storage of the fish in running sea water while it is being bled is preferable.

(5) For redfish, cutting blood vessels at the head and tail is the best of the conventional methods of bleeding.

References

JONES, N R In *Fish Handling and Preservation*, Paris, OECD, 1964 p. 31.

KELLY, T R and LITTLE, W T *J. Fd Technol.*, **1**, 121. 1966.

PARTMANN, W and GUTSCHMIDT, G *Kältetechnik*, **15**, 170. 1963

Quality of Sea Frozen Fish from the North-eastern Pacific Ocean

by N. Tomlinson, Shirley E. Geiger and S. W. Roach

Quality of sea frozen fish from the north-eastern Pacific Ocean

The keeping quality of several species of groundfish frozen at sea has been studied. The species examined were lingcod, Pacific cod, sablefish, red snapper, orange spotted rockfish, ocean perch, halibut and rock sole. The fish were frozen in blocks in a plate freezer and the frozen blocks were glazed before being stored.

Comparisons were made between fish frozen in various stages of *rigor mortis*. In addition, with sablefish, which is usually smoked, comparisons were made between fish frozen at sea and others frozen ashore after storage in ice or in a partially frozen condition.

In *pre-rigor* frozen fish, thaw contracture did not occur if the whole fish were thawed in water at 11°C (51.8°F) before being filleted. However, if the fish were filleted while frozen and the skinned fillets were then thawed, severe contracture occurred in lingcod, Pacific cod and halibut, but not in the other species. Contracture was confined chiefly to the red lateral muscle. When fillets from thawed fish were steamed, no clearly defined differences in texture were detected in the early stages of storage between fish frozen in different stages of *rigor mortis*; texture was related to flesh pH, toughness and dryness increasing with decreasing pH. This relationship seemed to become clearly evident only when the pH fell below about 6.5. In rock sole, when flesh pH was near 6.0 or lower, the flesh had the appearance of chalky halibut, being white and opaque.

A slight preference occurred for the flavour of the *pre-rigor* frozen fish with lingcod and Pacific cod, and for that of the *pre-* and *in-rigor* frozen fish with orange spotted rockfish and rock sole. When halibut were thawed, slight odours were detected in raw *post-rigor* frozen fish that were not evident in the other samples of this species.

When lingcod and halibut were thawed in water before being filleted or steaked, free drip from the cut portions was least in *pre-rigor* frozen fish.

Of the species examined, only in Pacific cod and halibut was a difference in the rate of protein denaturation eventually observed in relation to the stage of *rigor mortis* of the fish at freezing, the rate being higher in cod frozen *post-rigor* and in halibut frozen in *rigor* or *post-rigor*. Differences in texture were related to these differences in protein solubility.

Sablefish frozen at sea yielded a smoked product superior in flavour to other samples frozen after a period of 10 days storage in ice or in a partially frozen condition.

Qualité de poissons du pacifique nord-est congelés en mer

Les auteurs ont étudié la conservabilité de plusieurs espèces de poissons de fond congelés en mer: morue-lingue, morue de l'Alaska, morue charbonnière, "red snapper", "orange spotted rockfish", perche de mer, flétan et sole de roche. Les poissons ont été congelés en blocks sur un congélateur à plaques et les blocs congelés ont été givrés avant d'être entreposés.

Les poissons congelés à différentes phases de rigidité ont été comparés. De plus, pour la morue charbonnière, destinée généralement à être fumée, des comparaisons ont été faites entre des exemplaires congelés en mer et d'autres congelés à terre après entreposage dans la glace sous des conditions de congélation partielle.

Dans le poisson congelé avant le rigidité, la contractibilité à la décongélation ne se manifestait pas si le poisson avait été décongelé dans l'eau à 11°C (51.8°F) avant le filetage. Cependant, si le poisson était fileté en état de congélation, avec décongélation des filets dépouillés, on observait une contractibilité accentuée pour la morue-lingue, morue de l'Alaska et le flétan, mais non pour les poissons des autres espèces examinées. La contractibilité était généralement limitée au muscle latéral rouge. Après passage à la vapeur des filets provenant de poissons décongelés, on n'a pas décelé, en début d'entreposage, de nette différence de texture entre le poisson congelé à différentes phases de la *rigor mortis*. La texture a été mise en relation avec le pH de la chair, la coriacité et la siccité augmentant à mesure que s'abaissait le pH. Ce rapport n'a paru nettement marqué que lorsque le pH tombait audessous de 6,5. Dans la sole de roche, pour un pH très proche de 6,0, la chair devenait blanche et opaque, prenant l'apparence de flétan "crayeux".

Une légère préférence en matière de soût s'est manifestée pour le poisson congelé avant l'instauration de la rigidité cadavérique dans le cas de la morue-lingue et de la morue de l'Alaska, et pour le poisson congelé avant et pendant la rigidité dans le cas de l'"orange spotted rockfish" et de la sole de roche. Après décongélation du flétan, on a noté de légères odeurs dans la chair crue du poisson congelé *post-rigor* qui n'étaient pas apparues dans les autres échantillons de cette espèce.

Lorsque la morue-lingue et le flétan ont été décongelés dans de l'eau avant filetage ou tranchage, l'exsudat dans les morceaux coupés était moindre pour le poisson congelé *pre-rigor*.

Parmi les espèces examinées, seuls la morue de l'Alaska et le flétan ont manifesté une différence quant au taux de dénaturation des protéines observé en fonction du stade de la *rigor mortis* au moment de la congélation, le taux étant plus élevé pour la morue congelée *post-rigor* et pour le flétan congelé *in-rigor* ou *post-rigor* Les différences de texture ont été mises en rapport avec ces différences de solubilité protéinique.

La morue charbonnière congelée en mer a donné un produit fumé de qualité supérieure quant au goût à d'autres exemplaires de la même espèce congelés après une période d'entreposage de 10 jours dans la glace ou sous des conditions de congélation partielle.

La calidad del pescado marino congelado del océano pacífico nordoriental

Se ha estudiado la capacidad de conservación de varias especies de peces de fondo congelados en el mar. Las especies examinadas fueron: maruca, bacalao del Pacífico, pez sable, pargo colorado, cabracho moteado, gallineta, hipogloso y lenguado. Los peces se congelaron en bloques en un congelador de placas y los bloques congelados se glasearon antes de almacenarlos.

Se hicieron comparaciones entre los peces congelados en varias fases del *rigor mortis*. Además, con el pez sable, que se ahuma por lo general, se hicieron comparaciones entre el pez congelado en el mar y otros peces congelados en la costa después de almacenarlos en hielo o en condiciones de congelación parcial.

En el caso de los peces congelados antes del *rigor mortis*, si se descongelaba el pescado en agua a 11°C (51.8°F) antes de filetearlo, no había contracción. No obstante, si se fileteaban los peces ya congelados y a continuación se descongelaban los filetes sin la piel, la maruca, bacalao del Pacífico e hipogloso experimentaban contracción intensa, pero no otras especies. La contracción se limitaba principalmente al músculo rojo lateral. Cuando los filetes de pescado descongelado se trataron al vapor no se observaron diferencias claramente definidas de textura en los primeros períodos del almacenamiento entre los peces congelados en diferentes fases del *rigor mortis*; la textura estaba relacionada con el pH de la carne, y al disminuir éste aumentaban la aspereza y la sequedad. Esta relación parecía hacerse muy evidente sólo cuando el pH disminuía por debajo de 6,5 aproximadamente. En el caso del lenguado, cuando el pH se hallaba cerca o por debajo de 6,0 la carne tenía la apariencia yesosa que puede tener la de hipogloso, siendo blanca y opaca.

Se registró alguna diferencia en el sabor del pescado congelado antes de la rigidez en el caso de la maruca y el bacalao del Pacífico, y en el sabor del pescado congelado antes y durante la rigidez en el caso del cabracho moteado y del lenguado. Cuando se descongeló hipogloso, se detectaron ligeros olores en el pescado congelado crudo después de la rigidez, olores que no eran evidentes en las otras muestras de esta especie.

Cuando la maruca y el hipogloso se descongelaron en agua antes de filetearse o cortarse en rodajas, el exudado de las porciones cortadas fue menor en los peces que se habían congelado antes de la rigidez.

De las especies examinadas, sólo en el bacalao del Pacífico y en el hipogloso hubo una diferencia en el ritmo de alteración proteínica observada en relación con la fase de *rigor mortis* en que se encontraban los peces en el momento de la congelación, siendo más elevado el ritmo de alteración en el bacalao congelado después de presentada la rigidez y en el hipogloso congelado durante el *rigor* o *post-rigor mortis*. Las diferencias de textura se relacionaban con estas diferencias en la solubilidad proteínica.

El pez sable congelado en el mar dio un producto ahumado superior en sabor a otros ejemplares congelados después de un período de almacenamiento de 10 días en hielo o en condiciones de congelación parcial.

IN THE Canadian fishery of the north-eastern Pacific Ocean, largely because the fishing vessels are relatively small and the trips commonly of short duration, the usual practice is to freeze fish in shore plants rather than at sea. Consequently, with a few exceptions in which fish have been frozen at sea (Dassow and Stansby, 1952, with various flounders; Lantz, 1952, and Lantz and Carter, 1951, with halibut; Stansby and Dassow, 1951, with salmon for canning; and Wigutoff and Carlson, 1950, with groundfish), or killed from live tanks in the aquarium and frozen immediately (Jonas and Tomlinson, 1962; Tomlinson, Jonas and Geiger, 1963), the information available regarding the suitability for freezing and the frozen storage quality characteristics of species of commercial importance in the area is confined to that obtained through studies of fish frozen only after various periods of prior storage in ice (Dassow, 1956; Harrison and Roach, 1953; Heerdt and Stansby, 1954, 1955; Miyauchi and Alverson, 1955; Miyauchi and Stansby, 1952; Stansby, 1955; Stansby and Dassow, 1949; Stansby and Harrison, 1942; Stansby, Pottinger and Miyauchi, 1956; Tarr, 1941, 1945, 1946a, 1946b; Tarr and Sunderland, 1940; Wood and Haqq, 1961; Young, 1938, 1939), or after being frozen, thawed and refrozen (Miyauchi and Stansby, 1952; Tarr, 1946a). Hence, while much valuable knowledge applicable to the freezing and frozen storage of fish in this particular fishery has accumulated, little is known of the possible advantages or disadvantages of freezing at sea in comparison with present practice, particularly with respect to product quality. Thus Lantz and Carter (1951) reported a fairly marked preference by consumers for halibut frozen at sea at −17.8°C (0°F) and stored at −23.3°C (−10°F) in comparison with others iced for periods of 12 or 18 days, but halibut frozen after being stored in ice for three to five days was preferred over those frozen by air blast at sea (Lantz, 1952). Lantz (1952) reported that brill and rock sole frozen at sea were preferred to those iced and frozen later, and Dassow and Stansby (1952) found that flounders frozen at sea, or thawed and refrozen, were preferred to unfrozen market fillets. Stansby and Dassow (1951) found that salmon canned after being frozen were slightly inferior to those canned unfrozen, although the frozen fish could be held very much longer before being processed.

It appears that it would be desirable to have more information than is now available, not only for the species mentioned, but also for others of present or possible future commercial importance. This should include data on the influence, if any, of *rigor mortis* on quality and the possibility of the occurrence of thaw *rigor* with its occasional attendant excessive formation of free drip. Comparisons should be made with respect to shrinkage and quality changes between fish frozen at sea and fish handled by present methods which include icing and refrigerated sea water storage prior to freezing. The applicability of various methods for freezing at sea to different species should also be investigated.

The present report is confined chiefly to an investigation of the influence of *rigor mortis* on quality and of the occurrence of thaw *rigor*. A limited comparison of freezing at sea with the present practice as applied to sablefish subsequently used for smoking is also included.

METHODS AND MATERIALS

Fish* were caught by various commercial methods as indicated in the tables. They were eviscerated and, if not frozen at once, iced. The stage of *rigor mortis* was determined by examination of the flexibility of the fish and their firmness. With each species, fish taken from the same catch were frozen *pre-rigor*, *in-rigor* and *post-rigor*. Freezing was carried out in a vertical plate freezer in 45-kg (100-lb) blocks [10×61×110 cm (4×24×43 in.)] at −37°C (−34.6°F). The frozen blocks were glazed and stored at −34°C (−29.2°F). The glazing solution contained sodium chloride, 0.4 per cent and glucose 0.25 per cent.

At each sampling, three fish were examined from each treatment and the values recorded in the tables are in each case averages for three fish. With species other than halibut and sablefish, samples of lateral dorsal muscle (frozen) were taken from beneath the dorsal fin for measurement of protein nitrogen extractable in high ionic-strength salt solution (Dyer, French and Snow, 1950), of total protein nitrogen (Torten and Whitaker, 1964), and of acid labile phosphorus (ALP) (Tomlinson *et al.*, 1961). Extractable protein nitrogen (EPN) is reported as a percentage of the total protein nitrogen. For measurement of thaw contracture, a fillet was cut from one side of the body between the midpoint of the length and its tail, again while the fish was still frozen. The fillet was skinned and its length measured. It was then treated as for free drip measurement (see below), after which its length was remeasured. Contracture is reported as a percentage of the initial length of the fillet. Free drip was determined by a slight modification of the U.S. standard method for cod fillets (Anon., 1961) in which the time of holding at 20°C (68°F) was set at 2 h. In order to determine the possible influence of thaw *rigor* on free drip, the remainder of each sampled fish was

* The species of fish examined were: lingcod (*Ophiodon elongatus*), Pacific cod (*Gadus macrocephalus*), ocean perch (*Sebastodes alutus*), red snapper (*Sebastodes ruberrimus*), orange spotted rockfish (*Sebastodes maliger*), halibut (*Hippoglossus stenolepis*), rock sole (*Lepidopsetta bilineata*) and sablefish (*Anoplopoma fimbria*).

thawed in fresh water [at 10° to 11°C (50° to 52°F) for 2 to 4 h] after which a second skinned fillet was prepared from the previously uncut side and subjected to a free drip determination. Free drip is reported as a percentage of the initial weight of the fillet, "Fr" and "Th" in the tables indicating the drip from initially frozen and initially thawed fillets respectively. Flesh pH was measured in thawed fillets by means of a combination glass electrode thrust directly into the flesh. The pH meter was a Siebold model GLD. Texture and flavour were judged by three or four experienced members of the laboratory staff. Small portions of thawed fillets were wrapped in aluminium foil and steamed for 10 min for this purpose.

When halibut were to be examined, steaks 2.5-cm (1-in) thick were cut from the frozen fish. Samples for EPN and ALP measurements were taken from one half of the steak, the other half being skinned and used for contracture, free drip, flesh pH and taste and texture determinations. In the experiment with halibut, the same fish were sampled repeatedly during storage. The first sample was cut from the body at a position about 7.5 cm (3 in) posterior to the head and subsequent samples were taken progressively nearer the tail, a 6-mm (¼-in) thick steak being cut and discarded each time before the sample was taken. The fish were reglazed and returned to storage after each sampling.

Frozen sablefish were thawed, split, brined and then smoked by a commercial fish smoker. For comparison, sablefish stored in ice or in a partially frozen condition (Roach *et al.*, 1966) for 10 days, were deep frozen, thawed and smoked similarly. Present practice is to freeze and thaw sablefish before they are smoked, since this facilitates brining (Young, 1939; Sunderland, 1940).

RESULTS AND DISCUSSION

Detailed results are presented in tables 1 to 7. Before proceeding to a consideration of each species, several general observations can be made.

In freezing, it was found that lining the freezer with a polyethylene sheet (0.038 mm thick) before loading it with fish, obviated any difficulty in removing the frozen blocks from the freezer.

Pre- or *post-rigor* fish could be packed in the freezer more easily, and yielded frozen blocks with a more even surface which were less readily broken up during handling than did the blocks of fish frozen *in-rigor*.

As could be anticipated in view of the storage conditions [temperature −34°C (−29°F), heavy glazing] serious development of oxidative rancidity was not encountered, but slight rancidity was detected in the red lateral muscle of individual fish from time to time. Its appearance did not seem to be related to the stage of *rigor mortis* in which the fish were frozen.

Throughout the work a relation between texture and flesh pH was observed. Toughness and dryness increased with decreasing pH, but this was clearly evident only when the pH fell to below about 6.5.

No clear evidence for any tendency toward a decrease in the severity of thaw contracture or in the ALP concentration in the flesh of *pre-rigor* frozen fish during storage has been observed. In view of the duration and temperature of storage this is in accordance with expectations (Tomlinson, Jonas and Geiger, 1963).

Lingcod

Thaw contracture was severe in frozen fillets cut from fish frozen *pre-rigor*, and was accompanied by an approximate doubling in the quantity of free drip (table 1). The total drip was not excessive, however, and it seems probable the contracted and distorted appearance of the fillets would more likely cause difficulty. Thawing of fish in water at 10° to 11°C (50°C to 52°F) prior to filleting prevented thaw contracture (Jones, 1965), and free drip from fillets cut from thawed fish was least in fish frozen *pre-rigor*. Drip was greater from fillets taken from thawed fish frozen *in-rigor* or *post-rigor* than it was from fillets cut while these fish were still frozen. Occurrence of thaw

TABLE 1. FROZEN STORAGE OF LINGCOD

Rigor stage at freezing*	Storage time† (days)	Drip Fr (%)	Drip Th (%)	Thaw contracture‡ (%)	Flesh pH	EPN (%)	ALP White muscle (μM/g)	ALP Red muscle (μM/g)	Taste and texture
Pre	8	4.8	1.7	47	6.89	90	7.3	—	Taste very good, but some loss of sweetness in "*In*" and "*Post*". Texture good; "*In*" a little less tender than others
In	7	1.3	2.0	14	6.48	92	<0.5	—	
Post	2	1.7	2.3	7	6.86	93	1.5	—	
Pre	61	4.9	2.5	42	6.79	83	7.6	12.4	Taste very good, but sweetness lost in all red muscle.
In	60	2.9	3.5	6	6.57	81	0.5	2.0	
Post	55	3.3	3.0	3	6.67	81	2.0	2.8	Lower flesh pH a little tough
Pre	125	5.1	2.5	26	6.82	84	12.6	10.4	*Idem*
In	124	2.3	5.4	6	6.74	82	4.4	5.4	
Post	119	2.3	4.3	3	6.58	80	2.5	2.3	
Pre	183	5.7	2.1	44	6.77	87	19.5	11.9	*Idem*
In	182	3.3	2.7	4	6.66	87	5.6	6.2	
Post	177	3.8	4.7	4	6.69	88	5.9	4.7	
Pre	—	—	—	—	—	—	—	—	*Idem*
In	280	1.9	3.2	5	6.46	86	7.1	3.5	
Post	275	2.4	3.4	2	6.71	91	8.8	2.3	

* Fish caught by longline near Porlier Pass and killed from live well about 48 h later, on 4th May 1966. Flesh temperature, 10°C. *Pre-rigor*, into freezer between 1 and 3 h after being killed; *in-rigor*, 24 h; *post-rigor*, 144 h (most fish still *in-rigor* at 120 h). Fish beheaded and eviscerated then iced until frozen.

† From time of freezing.

‡ Occurred only in fillets cut before being thawed. Contracture chiefly in red muscle. *Pre-rigor* fillets curled badly.

contracture was related to the presence in the flesh of the *pre-rigor* frozen fish of a relatively high concentration of ALP in comparison with that in fish frozen *in-* or *post-rigor*. Contracture was most pronounced in red muscle; blocks of ordinary muscle cut from the same fish contracted very little or not at all, in agreement with the earlier observations of Buttkus (1963).

Initially, there were small but distinct differences in flavour between fish frozen *pre-rigor* and fish frozen *in-rigor* and *post-rigor*. Flesh from *pre-rigor* frozen fish was slightly and pleasantly sweet, particularly the red lateral muscle, while that from *rigor* and *post-rigor* samples was in some instances very slightly fishy. These differences tended to disappear during storage, and were perhaps exaggerated in this species because of the lengthy time involved in the development and resolution of *rigor mortis*. In this latter connection, it is interesting that several fish were observed to struggle quite vigorously when removed from ice 18 h after having been beheaded and gutted.

Reduction in protein extractability and changes in texture during storage proceeded very slowly and in these respects no differences have yet been detected in lingcod between fish frozen in different stages of *rigor*. Such differences as have been noted in texture appear to have been related to differences in flesh pH, as mentioned above.

Pacific cod

Thaw contracture occurred during the thawing of fillets from *pre-rigor* frozen fish (table 2). It was less severe than that observed in lingcod, but again was associated with increased free drip and a somewhat higher concentration of ALP. Thawing of the fish before they were filleted prevented thaw contracture. Free drip from this species was considerably higher and more variable than that from lingcod under all conditions.

The percentage of EPN decreased more rapidly during storage than it did in lingcod, and there was a tendency for the decrease to proceed more quickly in fish frozen *post-rigor*. There was also a tendency for the flavour of *pre-rigor* frozen fish to be preferred, but no distinct differences in texture were found between fish frozen in different stages of *rigor mortis*.

Ocean perch, red snapper and orange spotted rockfish

In each of the three species of rockfish examined (tables 3, 4 and 5) thaw contracture was very slight and exerted no detectable effect on the quantity of free drip, which was smallest in ocean perch and greatest and most variable in orange spotted rockfish. The lack of any strong thaw contracture in these species probably resulted from the negligible differences between the ALP concentrations found in the flesh of fish frozen in different stages of *rigor mortis*, and may also have been influenced by the noticeably more rigid structure of the fillets in comparison with those from lingcod and Pacific cod.

The percentage of EPN did not change detectably in any of these fish during the first 8½ months of storage, and no differences in texture associated with the stage of *rigor mortis* in which the fish were frozen were noticed. With orange spotted rockfish there was a slight preference for the flavour of the *pre-* and *in-rigor* frozen fish. The quite marked difference between ocean perch and red snapper in apparent keeping quality that was observed by Miyauchi and Stansby (1952) has not been evident in the present work. This might be attributed to the freezing, thawing and refreezing of the red snappers which occurred in the earlier work.

Halibut

In *pre-rigor* frozen halibut (table 6) thaw contracture in the red muscle was moderately severe, but was not detectable in the ordinary muscle. Contracture caused no measurable increase in free drip in this instance, however, probably because the fish were cut in steaks and the red muscle was able to tear a large proportion of its length free from the underlying ordinary muscle and consequently did not distort it. If the fish had been filleted rather than steaked it seems likely that some increase in

TABLE 2. FROZEN STORAGE OF PACIFIC COD

Rigor stage at freezing*	Storage time† (days)	Drip Fr (%)	Drip Th (%)	Thaw contracture‡ (%)	Flesh pH	EPN (%)	ALP White muscle (μM/g)	ALP Red muscle (μM/g)	Taste and texture
Pre	7	9.2	4.9	35	6.46	93	2.7	—	Taste good, including belly
In	7	4.1	5.2	14	6.48	95	<0.5	—	flaps. Texture generally
Post	1	2.5	5.2	0	6.59	91	<0.5	—	good, but less tender with lower pH
Pre	61	6.8	9.9	15	6.31	76	8.3	5.2	Texture fairly good, "*In*"
In	61	3.7	7.1	4	6.45	82	4.6	5.4	and "*Post*" very slight off
Post	55	3.8	9.4	3	6.29	75	4.6	4.3	flavour
Pre	125	11.3	7.5	25	6.34	87	6.5	6.3	Texture fairly good. Slight
In	125	6.8	6.7	5	6.42	77	4.8	5.8	preference for "*Pre*"
Post	119	11.7	10.3	4	6.55	62	2.3	5.1	
Pre	214	7.4	5.9	25	6.44	82	8.5	7.4	Texture fairly good. Slight
In	214	4.3	5.4	2	6.42	72	4.4	5.4	preference for "*Pre*" and
Post	208	5.4	6.8	0	6.41	72	3.1	4.3	"*In*". "*Post*" slightly dry
Pre	305	9.5	8.3	31	6.33	73	7.4	8.1	No rancidity. Flavour
In	305	4.3	6.9	4	6.42	83	5.1	6.3	good. "*Post*" dry and tough
Post	299	6.6	10.0	1	6.26	64	3.0	2.2	

* Fish caught by bottom trawl near north end of Vancouver Island on 2nd June 1966. Flesh temperature of 12°C. *Pre-rigor* into freezer 1 h after being caught; *in-rigor* 8¼ h; *post-rigor*, 106 h. Fish eviscerated then iced until frozen.

† From time of freezing.

‡ Occurred only in fillets cut before being thawed.

TABLE 3. FROZEN STORAGE OF OCEAN PERCH

Rigor stage at freezing*	Storage time† (days)	Drip Fr (%)	Drip Th (%)	Thaw contracture‡ (%)	Flesh pH	EPN (%)	ALP White muscle (μM/g)	ALP Red muscle (μM/g)	Taste and texture
Pre	25	3.1	2.2	7	6.75	81	6.4	4.7	Good
In	24	1.7	1.7	3	6.79	87	2.7	3.2	
Post	21	2.3	2.0	1	6.69	92	2.9	5.8	
Pre	79	3.3	3.0	9	6.75	91	3.8	6.2	Good. No rancidity. Fillets
In	78	2.4	3.2	6	6.60	87	3.1	7.6	discoloured when thawed.
Post	75	3.2	2.7	5	6.61	85	1.8	6.7	Looked white when cooked. No difference between *rigor* stages
Pre	176	2.7	2.6	4	6.89	88	5.9	3.7	Good. No rancidity. Fillets
In	175	2.6	3.8	2	6.80	90	3.9	5.4	discoloured on thawing.
Post	172	2.5	2.7	1	6.82	89	2.6	2.3	Slightly coloured on cooking. No difference between *rigor* stages
Pre	261	3.4	3.8	8	6.56	83	5.4	3.8	Good. No rancidity.
In	260	2.1	3.0	3	6.80	88	2.4	3.8	
Post	257	3.3	3.5	—	6.67	86	1.3	3.8	"*Post*" slightly tougher

* Fish caught by trawl near Bull Harbour on 28th August 1966. Flesh temperature 10°C. *Pre-rigor* into freezer 1 h after being caught; *in-rigor* 10 h; *post-rigor* 96 h. Fish eviscerated then iced until frozen.
† From time of freezing.
‡ In fillets cut before being thawed.

TABLE 4. FROZEN STORAGE OF RED SNAPPER

Rigor stage at freezing*	Storage time† (days)	Drip Fr (%)	Drip Th (%)	Thaw contracture‡ (%)	Flesh pH	EPN (%)	ALP White muscle (μM/g)	ALP Red muscle (μM/g)	Taste and texture
Pre	1	1.8	3.6	4	6.74	84	0.9	—	Taste very good. Texture rather coarse
In	1	2.3	2.8	4	6.85	85	<0.5	—	
Post	15	3.7	3.6	0	6.95	83	1.1	—	
Pre	68	2.3	3.2	0	6.85	80	—	—	*Idem*
In	68	4.5	3.8	0	6.85	89	—	—	
Post	53	5.1	5.7	0	6.75	89	—	—	
Pre	127	5.3	3.8	9	7.06	82	2.5	6.8	*Idem*
In	127	3.8	4.8	5	6.69	91	3.3	3.6	
Post	112	3.5	4.7	6	6.75	91	2.3	3.5	
Pre	219	3.9	4.3	2	6.72	85	3.8	3.8	*Idem*. No rancidity
In	219	3.1	3.7	0	6.83	92	3.3	2.5	
Post	204	4.0	6.5	0	6.77	86	2.9	2.4	
Pre	306	2.8	3.7	—	6.85	83	3.8	3.5	"*Pre*" preferred. Texture
In	306	2.9	5.5	—	6.79	83	4.0	4.1	and taste good. No
Post	297	4.2	5.8	—	6.70	83	2.7	2.9	rancidity

* Fish caught by longline near S.W. corner of Lasqueti Island on 11–12th June 1966. Flesh temperature 10°C, *pre-rigor* into freezer 3 h after being caught; *in-rigor* 6 h; *post-rigor* 72 h. Fish eviscerated then iced until frozen.
† From time of freezing.
‡ In fillets cut before being thawed.

TABLE 5. FROZEN STORAGE OF ORANGE SPOTTED ROCK FISH

Rigor stage at freezing*	Storage time† (days)	Drip Fr (%)	Drip Th (%)	Thaw contracture‡ (%)	Flesh pH	EPN (%)	ALP White muscle (μM/g)	ALP Red muscle (μM/g)	Taste and texture
Pre	8	3.4	8.2	2	6.84	74	4.7	5.5	Taste very good. Very slight preference for "*Pre*" and "*In*". Texture good
In	8	4.0	7.2	2	6.92	77	7.0	4.8	
Post	6	4.8	7.0	5	6.68	80	8.6	5.1	
Pre	69	6.8	5.7	6	6.88	90	4.0	6.5	Taste and texture good. "*Post*" texture less tender
In	69	4.5	6.3	4	6.81	85	1.9	7.5	
Post	68	8.1	5.8	3	6.72	83	3.1	6.5	
Pre	132	4.7	3.6	3	6.94	86	4.3	7.7	Taste and texture good. One rancid red muscle ("*Pre*")
In	132	7.0	6.2	1	6.68	68	3.6	6.3	
Post	131	3.9	8.1	0	6.65	81	3.1	5.6	
Pre	223	4.3	5.8	2	6.88	87	3.4	7.9	Taste and texture good. "*Pre*" and "*In*" preferred
In	223	3.0	5.8	—	6.71	90	2.7	3.1	
Post	221	3.5	5.7	—	6·70	84	0·2	2.6	

* Fish caught by longline near north end of Johnstone Straight on 11–12th July 1966. Flesh temperature 12°C. *Pre-rigor* into freezer ½ h after being caught; *in-rigor* 4 h; *post-rigor* 48 h. Fish eviscerated then iced until frozen.
† From time of freezing.
‡ In fillets cut before being thawed.

free drip might have occurred. Free drip was least from fish frozen *pre-rigor*. The possibility exists that this difference may have been influenced to some extent by flesh pH (Tomlinson, Geiger and Dollinger, 1966).

The *post-rigor* frozen fish were of somewhat poorer texture than the others, but whether this should be attributed to the stage of *rigor mortis* or to flesh pH is at present uncertain. No detectable decrease in percentage of EPN occurred in any of the fish during the first six months of storage and no differences related to *rigor mortis* were observed. But by 15 months small decreases in EPN were detected and there appeared to be a tendency for this to be greater in fish which was frozen *in-rigor* or *post-rigor*. When the raw fish were thawed, slight odours were detected from the *post-rigor* frozen fish but not from the others.

Rock sole

As in the rockfishes, thaw contracture was slight in *pre-rigor* frozen fish and did not increase free drip, which in this species was particularly high in fillets cut from water-thawed fish (table 7).

The percentage of EPN did not decrease appreciably during seven months of storage and no clear relation between EPN and stage of *rigor mortis* was evident. A very slight preference for the taste of *pre-* and *in-rigor* frozen fish appeared, but otherwise no differences possibly attributable to *rigor mortis* were detected.

The flesh pH of the rock soles was lower than that of the other species examined and probably contributed to their rather chewy texture. The flesh of several individual fish whose pH was just below 6.0, or very slightly above it, closely resembled that of chalky halibut in appearance,

TABLE 6. FROZEN STORAGE OF HALIBUT

Rigor stage at freezing*	Storage time† (days)	Drip (%)	Thaw contracture‡ (%)	Flesh pH	EPN (%)	ALP White muscle (μM/g)	ALP Red muscle (μM/g)	Taste and texture
Pre	9	5.0	31	6.66	93	2.5	—	Taste very good. Slight odour from "*Post*" when thawed. Texture good
In	8	5.0	10	6.64	92	<0.5	—	
Post	6	6.6	0	6.44	95	<0.5	—	
Pre	60	4.5	28	6.65	93	1.7	3.8	Taste very good, texture good. "*Post*" least tender
In	59	5.5	7	6.59	88	<0.5	2.0	
Post	57	6.5	7	6.42	91	0.8	1.1	
Pre	125	7.1	30	6.54	88	7.0	5.4	Taste good, texture good in "*Pre*" and "*In*", fair in "*Post*"
In	124	8.6	10	6.57	94	3.1	1.9	
Post	122	9.1	4	6.37	88	5.1	3.9	
Pre	183	5.1	37	6.60	94	3.6	8.4	"*Pre*" and "*In*" good. "*Post*" taste good, but drier
In	182	6.4	17	6.58	94	2.2	4.2	
Post	180	6.2	0	6.35	93	1.4	3.1	
Pre	281	4.9	27	6.51	94	3.5	6.2	"*Pre*" and "*In*" good. "*Post*" drier, but good flavour
In	280	7.2	6	6.46	92	3.3	3.9	
Post	278	7.1	2	6.33	94	4.4	3.6	
Pre	364	5.9	11	6.55	92	4.7	5.6	"*Pre*" good flavour and texture. "*In*" drier but good flavour. "*Post*" dry
In	363	8.7	5	6.38	86	4.4	3.3	
Post	361	7.0	5	6.36	83	4.6	3.3	
Pre	455	7.6	9	6.27	87	3.8	3.9	Good flavour, no rancidity. "*Pre*" preferred—slightly dry. "*In*" and "*Post*" dry
In	454	7.8	3	6.32	84	3.3	3.6	
Post	452	10.8	2	6.25	82	3.2	3.5	

* Fish caught by longline near Goose Island on 9–10th May 1966. Temperature of flesh when caught 8°C. *Pre-rigor* into freezer in less than 2 h of being caught; *in-rigor* between 13 and 20 h; *post-rigor* between 48 and 72 h. Fish eviscerated, then iced until frozen.
† From time of freezing.
‡ These fish were cut in steaks, only red muscle contracted measurably.

TABLE 7. FROZEN STORAGE OF ROCK SOLE

Rigor stage at freezing*	Storage time† (days)	Drip Fr (%)	Drip Th (%)	Thaw contracture‡ (%)	Flesh pH	EPN (%)	ALP White muscle (μM/g)	ALP Red muscle (μM/g)	Taste and texture
Pre	12	6.0	11.5	6	6.16	78	2.6	2.8	Taste good. Texture somewhat chewy, tends to follow pH—the lower the tougher
In	12	4.4	9.2	2	6.27	81	2.6	3.0	
Post	11	6.6	9.4	1	6.15	79	3.3	3.2	
Pre	77	9.0	14.2	9	6.12	88	3.8	3.0	*Idem*. Slight rancidity some samples
In	77	7.7	12.2	5	6.22	83	2.4	4.6	
Post	76	6.4	10.2	6	6.09	81	2.6	1.8	
Pre	134	3.5	8.3	3	6.13	86	5.6	3.8	*Idem*. Slight preference for "*Pre*" and "*In*". Only one slight rancid ("*Pre*")
In	134	5.8	9.9	2	6.02	84	4.5	5.3	
Post	133	6.9	7.6	2	6.03	78	4.0	2.7	
Pre	225	4.2	10.9	5	6.17	85	4.5	2.3	*Idem*. Slight preference for "*Pre*". No rancidity in any sample
In	225	7.4	10.3	1	6.13	87	3.5	5.8	
Post	224	6.6	12.0	2	6.10	85	1.5	2.2	

* Fish caught by bottom trawl near Cape Scott on 11th July 1966. Flesh temperature 12°C. *Pre-rigor* into freezer 3 h after being caught; *in-rigor* 6 h; *post-rigor* 19 h. Fish eviscerated then iced until frozen.
† From time of freezing.
‡ In fillets cut before being thawed.

being white and opaque in contrast to the translucent appearance of flesh from fish of slightly higher pH (Tomlinson, Geiger and Dollinger, 1965).

Sablefish

Sablefish were caught by longline near Fitzhugh Sound on 21st May 1966. As described in detail above, some were frozen at once while others were stored in ice or partially frozen for 10 days and then were deep frozen. The fish were subsequently thawed and smoked and then compared for flavour, texture and appearance.

While fish from different treatments possessed similar appearance and texture, flavour differences were obvious, particularly in the red lateral muscle in which an objectionable off-flavour occurred in both the iced and partially frozen fish, which was not observed in the fish frozen at sea. The partially frozen fish had slightly more rancid flavour than did the iced fish and were slightly more salty. After two months of additional frozen storage before being smoked, the defect in flavour appeared to be slightly more pronounced in the initially iced and partially frozen fish. The sablefish used were smaller and less mature than those customarily used commercially and this may have accentuated some of the defects observed.

References

ANON. 1961 Inspectors' instructions for grading frozen cod fillets. U.S. Bureau of Commmercial Fisheries, Washington, D.C., pp. 24–26.

BUTTKUS, H 1963 Red and white muscle of fish in relation to *rigor mortis*. *J. Fish. Res. Bd Can.*, **20**, 45–58.

DASSOW, J A 1956 Fish. In *Refrigeration of Fish—Part 4*, Fishery Leaflet 430, U.S. Fish and Wildlife Service, Washington, D.C., pp. 1–36.

DASSOW, J A and STANSBY, M E 1952 Refrozen fillets from fish frozen in the round at sea. *Seattle manuscript report*, No. 13, U.S. Bureau of Commercial Fisheries, 11 pp.

DYER, W J, FRENCH, H V and SNOW, J M 1950 Proteins in fish muscle. 1. Extraction of protein fractions in fresh fish. *J. Fish. Res. Bd Can.*, **7**, 585–593.

HARRISON, J S M and ROACH, S W 1953 Brine freezing of fish. *Prog. Rep. Pacif. Cst Stns*, **94**, 3–4.

HEERDT, JR, M and STANSBY, M E 1954 Freezing and cold storage of Pacific northwest fish and shellfish. Part III. Storage characteristics of six species of oily fish. *Comml Fish. Rev.*, **16**, 1–5.

HEERDT, JR, M and STANSBY, M E 1955 Freezing and cold storage of Pacific northwest fish and shellfish. Part IV. Storage characteristics of four species of salmonidae. *Ibid.*, **17**, 13–17.

JONAS, R E E and TOMLINSON, N 1962 The phospholipid content of lingcod muscle during frozen storage. *J. Fish. Res. Bd Can.*, **19**, 733–734.

JONES, N R 1965 Problems associated with the freezing of very fresh fish. In *Fish Handling and Preservation*, Paris, OECD, p. 31.

LANTZ, A W 1952 Freezing British Columbia fish at sea. II. *Prog. Rep. Pacif. Cst Stns*, **92**, 21–22.

LANTZ, A W and CARTER, N M 1951 Freezing British Columbia fish at sea. *Ibid.*, **88**, 57–60.

MIYAUCHI, D T and ALVERSON, D L 1955 Freezing and cold storage of Pacific northwest fish and shellfish. Part V. Palatability and cold-storage life of blacktip rockfish (*Sebastodes aleutianus*) and flag rockfish (*Sebastodes rubrivinctus*). *Comml Fish. Rev.*, **17**, 17–18.

MIYAUCHI, D T and STANSBY, M E 1952 Freezing and cold storage Pacific northwest fish and shellfish. Part I. Storage life of various rockfish fillets. *Ibid.*, **14**, 24–28.

ROACH, S W, TOMLINSON, N, GEIGER, S E and DOLLINGER, E 1966 Partial freezing as a means of preserving various species of groundfish. *J. Fish. Res. Bd Can.*, **23**, 701–713.

STANSBY, M E 1955 Packaging frozen fish in tin results in superior storage life. *Comml Fish. Rev.*, **17**, 17–20.

STANSBY, M E and DASSOW, J 1949 Storage life of whole and split rockfish fillets. *Ibid.*, **11**, 1–8.

STANSBY, M E and DASSOW, J 1951 Use of frozen salmon for canning. *Ibid.*, **13**, 20–25.

STANSBY, M E and HARRISON, R W 1942 Preliminary investigation of methods for freezing and storing fillets of some Pacific northwest fish. In *Spec. Sci. Rpt. No.* 15, U.S. Fish and Wildlife Service, Washington, D.C., 25 pp.

STANSBY, M E, POTTINGER, S R and MIYAUCHI, D T 1956 Factors to be considered in the freezing and cold storage of fishery products. In *Refrigeration of Fish—Part 3*, Fishery Leaflet 429, U.S. Fish and Wildlife Service, Washington, D.C., 65 pp.

SUNDERLAND, P A 1940 Canned smoked black cod (sablefish). *Prog. Rep. Pacif. Cst Stns*, **46**, 3–5.

TARR, H L A 1941 Formation of drip in fish muscle and its control in defrosted fish. *Ibid.*, **47**, 5–9.

TARR, H L A 1945 Control of rancidity in stored fish. *Ibid.*, **64**, 57–61.

TARR, H L A 1946a Control of rancidity in stored fish. II. *Ibid.*, **66**, 17–20.

TARR, H L A 1946b Control of rancidity in stored fish. III. *Ibid.*, **68**, 52–54.

TARR, H L A and SUNDERLAND, P A 1940 Drip in unfrozen and frozen fillets controlled by brining. *Ibid.*, **45**, 19–20.

TOMLINSON, N, ARNOLD, E S, ROBERTS, EVE and GEIGER, S E 1961 Observations on *post-mortem* biochemical changes in fish muscle in relation to *rigor mortis*. *J. Fish. Res. Bd Can.*, **18**, 321–336.

TOMLINSON, N, GEIGER, S E and DOLLINGER, E Chalkiness in
1965 halibut in relation to muscle pH and protein denaturation. *Ibid.*, **22**, 653–663.

TOMLINSON, N, GEIGER, S E and DOLLINGER, E Free drip,
1966 flesh pH, and chalkiness in halibut. *Ibid.*, **23**, 673–680.

TOMLINSON, N, JONAS, R E E and GEIGER, S E Glycolysis in
1963 lingcod muscle during frozen storage. *Ibid.*, **20**, 1145–1152.

TORTEN, J and WHITAKER, J R Evaluation of the biuret and
1964 dye-binding methods for protein determination in meats. *J. Sci. Fd Agric.*, **29**, 168–174.

WIGUTOFF, N B and CARLSON, C B S.S. *Pacific Explorer.*
1950 Part V. 1948 operations in the North Pacific and Bering Sea. In Fishery Leaflet 361, U.S. Fish and Wildlife Service, Washington, D.C., 161 pp.

WOOD, J D and HAQQ, S A Fat hydrolysis in frozen fillets of
1962 lingcod and Pacific gray cod. *J. Fish. Res. Bd Can.*, **19**, 169–171.

YOUNG, O C The quality of fresh, frozen and stored halibut
1938 as determined by a tasting panel. *Prog. Rep. Pacif. Cst Stns*, **37**, 12–16.

YOUNG, O C Further tasting panel tests on frozen and stored
1939 fish. *Ibid.*, **42**, 16–20.

Influence of Timelag Prior to Freezing on the Quality of Redfish

by D. J. Tilgner and W. Rogoś

Influence of timelag prior to freezing on the quality of redfish

The effect of timelag prior to freezing on the quality of frozen redfish (*Sebastes marinus*) was investigated. For this purpose two lots of redfish from the same haul were filleted, frozen and cold-stored in an identical manner, except that one of the lots was filleted immediately after being brought aboard, prior to the onset of *rigor mortis*, and the other 68 hours later, after the resolution of *rigor mortis*. After three months, physical, chemical and organoleptic tests were carried out. The organoleptic tests showed that after this cold storage period, the quality of *pre-rigor* frozen redfish fillets was high from the commercial point of view, whereas the *post-rigor* frozen fillets were of only medium quality.

Influence qu'exerce sur la qualité de la rascasse du nord le temps écoule avant la congélation

Les auteurs ont étudié l'influence qu'exerce sur la qualité de la rascasse du Nord (*Sebastes marinus*) congelée le laps de temps s'étant écoulé avant la congélation. Deux lots de rascasses du Nord provenant de la même pêche ont été filetés, congelés et entreposés en chambre froide de manière identique, à une différence près: les poissons de l'un des lots ont été filetés immédiatement après leur sortie de l'eau avant l'apparition de la *rigor mortis*, et ceux de l'autre 68 heures plus tard, *post-rigor*. Au bout de trois mois ont été effectués des essais physiques, chimiques et organoleptiques. Sur la base des épreuves organoleptiques, après cette période de stockage les filets de rascasses du Nord congelés *pre-rigor* se sont révélés d'une haute qualité commerciale, tandis que les filets congelés *post-rigor* n'étaient que de qualité moyenne.

Influencia del tiempo transcurrido antes de la congelación sobre la calidad de la gallineta

Se ha estudiado el efecto que ejerce sobre la calidad de la gallineta (*Sebastes marinus*) congelada el período de tiempo que se deja transcurrir antes de la congelación: con este objeto se prepararon en filetes dos lotes de gallinetas de la misma redada, que se congelaron y almacenaron en frío en forma idéntica, con la única diferencia que uno de los lotes se cortó en filetes inmediatamente después de izado a bordo, antes de la aparición del *rigor mortis*, y el otro 68 horas más tarde, después de desaparecer el *rigor mortis*. Al cabo de tres meses se efectuaron pruebas físicas, químicas y organolépticas: estas últimas mostraron que después de este período de almacenamiento en frío, los filetes de gallineta congelada antes de la aparición de la rigidez eran de buena calidad desde el punto de vista comercial, mientras que los congelados *post-rigor* eran sólo de calidad intermedia.

REDFISH (*Sebastes marinus*) was caught in the month of May near the Labrador coast by a Polish factory trawler. From one of the hauls, fish taken at random were divided into two separate parts. One part was processed immediately prior to the development of *rigor mortis* and the other after relaxation and loss of stiffness. They were kept at 14°C (57°F) for full development of *rigor mortis* which took place after 24 h and lasted for 44 h, after which period the relaxed fish were processed identically as were the *pre-rigor mortis* samples.

The fish were filleted mechanically (using a Baader No. 150 machine), frozen in blocks in a tunnel freezer for 5 h to −25°C (−13°F), glazed, packed in cartons and stored at −23°C (−9°F) in the ship's freezer storage for two months, unloaded and kept for three days in a harbour freezer storage at −24°C (−11°F) and brought to the university's freezer facilities kept at −18°C (0°F).

The ship's usual procedure of trawling and processing was adhered to, the only difference being in the time-lag prior to filleting and freezing of the fish. The fish samples were taken from one of the hauls which usually lasted about 2 h and yielded about 15 to 20 t of fish.

ANALYTICAL METHODS

Twenty-eight frozen fillets were taken at random, 14 from blocks of the *pre-rigor* frozen fish and 14 from the *post-rigor mortis* fish. These were thawed in air to an internal temperature of 0°C (32°F). The following characteristics were examined:

(1) Loss of fluid after thawing.

(2) ATP content (Partmann, 1955 and 1960) by determination of inorganic phosphorus (Berenblum and Chain, 1958).

(3) Solubility of actomyosin (Pierszyna, 1958).

(4) pH of the water extract from comminuted fish muscle (Bykow, 1962).

(5) Juice retention (Grau and Hamm, 1953)—five determinations made on each fillet.

(6) Penetrometric tenderness (Tilgner, 1949) using a steel rod 6 mm wide, 0.3 mm blade thickness and 20° angle of the rod end—10 determinations in each fillet.

(7) Sensory qualitative and quantitative analysis by a qualified panel of seven persons using a five-level scale for scoring colour intensity, colour acceptability, texture, aroma intensity, aroma acceptability, tenderness, juiciness, flavour intensity and flavour acceptability. The over-all quality was also rated using the palatability rating scale (Peryam and Pilgrim, 1957). Each judge scored four fillets, two samples from each of the two different blocks.

Three determinations were made on each of the 28 fillets from the two different blocks for the characteristics listed under (2), (3) and (4).

Steaming procedure

The thawed fillets were simmered in moist heat on a rack in a covered casserole containing a small amount of water. In a preliminary study the optimum internal temperature for redfish meat was established by a panel

of 13 judges. Fillets were heated to six different internal temperatures: 82°C (180°F), 84°C (183°F), 86°C (187°F), 88°C (190°F), 90°C (194°F) and 92°C (198°F). The above-mentioned quality components of the samples, as mentioned under (7), as well as the over-all palatability were scored. The scoring results showed definitely that heating the fillets to an internal temperature of 90°C (194°F) produced the best cooked product. Hence this temperature was used in the main experiment.

RESULTS

A distinct difference was observed between redfish processed without any delay in the *pre-rigor* stage as compared with redfish which underwent the full *rigor mortis* changes during the 68 h waiting period before being processed.

(1) Loss of fluid during thawing of *pre-rigor mortis* processed redfish fillets amounted to 7 per cent as compared to 11.5 per cent for *post-rigor mortis* processed redfish.

(2) The ATP content in *pre-rigor* processed fish was, as expected, quite variable (0.69 to 5.19 mgP/100 g flesh) averaging 2.4 mgP while in the *post-rigor* processed fillets only residual amounts of ATP were found (0.07 to 0.80 mgP/100 g averaging 0.35). The large decrease in ATP-ase content conditions the relaxation of muscles although the conversion rate depends on the content of fat or glycogen, and temperature influences significantly the resynthesis and decomposition rates (Golovkin, 1966).

(3) In the *post-rigor* processed fillets 19.8 per cent less actomyosin was extracted as compared with the *pre-rigor* processed fillets (3.54 *vs.* 4.42 g/100 g). Under the influence of ATP-ase decomposition the actomyosin complex is converted into an undissociated form and becomes insoluble.

(4) The pH of the *pre-rigor* fillets was higher (average 6.78 ranging from 6.62 to 6.93) than in the *post-rigor* fillets (average 6.50 ranging from 6.38 to 6.61) corresponding with the ATP-content.

(5) The juice retention was better in the *pre-rigor* processed fillets (29.85 cm^2 as compared with 35.3 cm^2) which corresponds with a greater protein decomposition in the *post-rigor* processed fillets.

(6) The penetrometric tenderness was pronouncedly better (18.15 per cent) in the *post-rigor* processed fillets. These were softer and the 9-mm thick samples offered less resistance to the penetrating steel rod (414 g as against 508 g in the *pre-rigor* samples).

(7) The results of the sensory analysis gave a distinctively lower scoring of the cooked fillets processed in the *post-rigor* stage. The uniformity and acceptability of the colour and texture were lower as was the acceptability of aroma, juiciness and flavour.

FINAL REMARKS

From the commercial point of view, frozen redfish fillets, processed without delay in the *pre-rigor mortis* stage and stored for three months at −24° to −18°C (−11° to 0°F), air thawed and steam cooked to 90°C (194°F) internal temperature, possess a high sensory quality. Redfish processed after the *rigor-mortis* stage has only a medium quality after three months frozen storage due to grey colour, poorer texture, lessened juiciness and lowered aroma and flavour palatability. It should be pointed out that redfish fillets processed in the *pre-rigor* stage possess a limited storage life. Altogether 12 weeks of frozen storage [four weeks at −25°C (−13°F) in the ship's freezer and eight weeks at −15°C (5°F) on land] is the maximum storage life. After 16 weeks in frozen storage the sensory deterioration is well advanced and frozen redfish fillets are inedible (Tilgner, Ziemba and Chylińska, 1967).

Acknowledgments

The help of Dr. H. Daun, Senior Instructor in this faculty, in selecting and supervising the analytical procedure, and of Doz. Habil. Dr. Z. E. Sikorski for comments is acknowledged with sincere thanks. The captain and crew members of the factory trawler M/T *Jupiter* kindly co-operated in making possible the random sampling of the experimental fish at sea. The junior author W. Rogoś was a graduate student and a regular crew member.

References

BERENBLUM, L and CHAIN, E *Biochem. Z.*, **32**, 295.
1958

BYKOW, W P *Trudy vses. nauchno-issled. Inst. morsk. ryb.*
1962 *Khoz. Okeanogr.*, **45**, 5.

GRAU, R and HAMM, R *Fleischwirtschaft*, **5**, 11.
1953

GOLOVKIN, N A *Proceedings of the IInd International Congress*
1966 *of Food Science and Technology*, Warsaw, 161–169.

PARTMANN, W *Biochem. Z.*, **326**, 260.
1955

PARTMANN, W *Arch. FischWiss.*, **11**, 81.
1960

PERYAM, D R and PILGRIM, F J *Fd Technol., Champaign,*
1957 **11**(9), 9–14.

PIERSZYNA, L I *Piszc. Technol.*, **5**, 157.
1958

TILGNER, D J *Przem. rolny spożyw.*, **3**, 5.
1949

TILGNER, D J, ZIEMBA, Z and CHYLIŃSKA, E Low temperature
1967 storage limits of North Atlantic redfish fillets evaluated by sensory and chemical tests. *Report of the Sea Fisheries Institute*, Gdynia, 15b. (In press.)

DISCUSSION

Love (U.K.): The extent of drying of fish in an air-blast freezer is usually very small—Cutting, before the war, put the moisture loss at about 1 per cent. On the other hand, it is really not possible for plate-frozen material to show any genuine so-called "freezer-burn" at all, since the plates are in intimate contact with the wet fish and do not allow any moisture to escape. One does hear remarks from time to time that a certain plate-freezer gives a product that suffers from freezer-burn, but the inference is false. In reality, such a freezer is a good one, and is freezing the surface of the fish very rapidly. Such rapid freezing takes the form of extremely numerous

minute ice crystals, which scatter light and make the surface of the frozen muscle look a dense white. This is mistaken for freezer-burn, but after thawing the appearance of the fillet is indistinguishable from that obtained from more slowly-frozen, less white fillets. In genuine freezer-burn, where drying has occurred, the white appearance remains after thawing, because such muscle denatures and does not re-hydrate.

Jones (U.K.): On the question of the incidence of freezer-burn in plate-frozen material, I think this is an illustration of the variability of fish under different conditions of freezing and processing. What we have to avoid here is dogmatic statements on questions of which we have incomplete knowledge—for instance the water-binding capacity of fish tissue in varying physiological condition and which has been frozen in plate freezers of poor design.

Dyer (Canada): In his review paper, Jones has noted the effect on quality of rough handling of fish which are partially stiff, due either to *rigor* development or because they have been frozen and only partially thawed. This topic could be important in handling fish from frozen blocks, since these are sometimes filleted in a partially thawed condition. Has any evidence been published on the effect of such handling on quality in partly frozen fish?

Jones (U.K.): My comment was mainly directed to situations where fish was hard either because of the *rigor* condition or deep freezing. However, I have seen naturally "soft" fish such as hake suffer from filleting in the semi-frozen condition.

Tomiyama (Japan): In his paper, Jones mentions the possibility of upgrading the flavour quality of fillets by including nucleotides. So far as our experiments go, IMP is readily split by 5-nucleotidase of the fillet. It may be of interest to note that enzymatic cleavage of 5-P can be inhibited by simultaneous use of chelating agents, such as polyphosphate and citrate, which inactivate magnesium ion, as an enzyme activator.

MacCallum (Canada): I wish (1) to take note of the valuable contribution Jones has made, especially in organizing and summing up the results of present research in tabular form and (2) to point out that recent work of MacCallum *et al.* ("Condition of Newfoundland trap-caught cod and its influence on quality after single and double freezing", submitted to *J. Fish. Res. Bd. Can.*) shows the possibility of avoiding Fault C (reported in Table 2 of Jones' paper) by using frozen storage to best advantage, in this case by storing the fish sufficiently long at available temperatures to avoid short, granular or mealy texture and thus obtain the preferred textural qualities. The degree of intensity of mealiness and short-grained features in freshly frozen (once) trap cod (*Gadus morhua*) correlated significantly with the level of ATP immediately prior to cooking, the more mealy fish having higher values of ATP. Fillets frozen before *rigor* toughened very slowly in storage at −23°C (−10°F) and the mealy condition eventually disappeared; hence fish that were downgraded for mealiness at freezing actually improved or at least maintained initial overall texture scores during the first six months in storage, a result not previously reported in the literature. The panel showed a clear preference for *pre-rigor* frozen over *in-rigor* frozen material. With the trap cod it was shown also that differences in *pre-rigor* and *in-rigor* chilled fish at freezing, as assessed by muscle glycogen, lactate and reserves of ATP, resulted in differences in thaw-drip and pH; it would appear that patterns in texture may be predicted by the amounts of thaw-drip and the pH measured in the cold-stored pack. The benefit of a temperature lower than that presently available commercially was demonstrated using frozen blocks of unfilleted cod prepared from "commercial-like" uniced landings. These blocks were stored at −46°C (−50°F) before subsequent thawing, processing, refreezing and storage at −23°C (−10°F). The twice-frozen product was quite satisfactory, being equal in quality to fillets of iced-at-sea fish frozen only once but stored continuously at −23°C (−10°F).

Jones (U.K.): Several main points have emerged from our deliberations.

Firstly, in *pre-rigor* operations, contraction effects are critical. These relate on the one hand to shrinkage, drip-loss and mealiness and on the other to the very bad break-up effects we've heard about. Secondly, the pH of the muscle is the critical factor in determining initial texture and it may be relevant throughout storage. It also critically affects drip-loss, of course. Thirdly, bleeding technique is a prerequisite for good appearance. It appears that chilling is essential. The best economic method is perhaps open to question. We're not quite sure from these papers or from the earlier literature whether bleeding technique is very relevant to longer term keeping quality as against appearance. I think it would be useful if we could have a comment on the effectiveness of gutting as a bleeding operation to avoid any double handling difficulties that one might have on a trawler.

There appears to be a general feeling that for many species, the *pre-rigor* freezing operation, beset with difficulties as it is, can commend very considerable advantages quality-wise as compared with later freezing. I suggest we could profitably, perhaps, concentrate on a discussion as to how we can control these factors, particularly in the practical sense, or perhaps how we can attempt to obviate the effects of earlier malpractice. This goes back to the point concerning the upgrading of rather poor material which was raised in my paper, and also by Tomiyama. I think there is quite a big future in this. For instance, in relation to both of these points, can we control killing methods? We've not heard too much about this but the work of Bramstedt and others has pointed out that one can control ATP concentrations at death quite easily by electrical killing methods. Then again can we lower the pH of fish that is in poor nutritional condition and get any consequent improvement in texture in material that has been frozen and thawed? If we are unfortunate enough to come across conditions of high temperature *rigor* and very bad gaping effects, can we stick these fillets together again very easily? I think there are distinct possibilities here and, of course, there has been some work done to this effect in different institutes.

Another main point concerns the question of how far quality control people, using methods such as the cell fragility technique or ATP determination, pH measurement, or other measurements, aid the processor in designing his day-to-day operations. Obviously from what we've heard, and for that matter what I indicated in my paper, he has got to be a rather versatile man in his approach to his problems.

Templeton (U.K.): Love made the point that if whole cod are frozen *in-rigor* there may be a considerable amount of gaping in the thawed fillet and, in order to prevent it, the cod should be frozen *pre-rigor*. Although gaping is a problem, an even greater problem faced by the British freezer trawler fleet is that of blood discolouration of the fillets from thawed whole fish. Kelly has given us some interesting results on the bleeding of whole fish. He shows that with the present procedures for bleeding cod on British trawlers, i.e. gutting, blood discolouration will be at a minimum when the fish is allowed to go into *rigor*. Therefore, I would suggest that a compromise will have to be made between these requirements for the prevention of gaping and blood discolouration.

Kelly (U.K.): I have some remarks to make as regards Love's observations of "gaping" in cod fillets. During the summers of

1965 and 1966 I was investigating the quality of cod caught during the trap-fishing season in Newfoundland. The major problem which emerged with these fish was the softening of the flesh which resulted in severe gaping of the fillets after cutting. The effect of this was to make trimming extremely slow as the fillets literally "fell apart" and yields after skinning and trimming were poor. From my observations and measurements I found that the worst affected were fish which fell to the lowest *post mortem* pH values, that is the fish which were in the best nutritional state. This agrees with what Love has just said.

I concluded that the softening was the result of a combination of not only this intensive feeding but also holding the fish at high ambient temperatures and possibly the fact that the fish were of young stock. As regards the last point, gaping appears to be the result of a breakdown of the connective tissue. It is generally accepted that collagen, the main protein constituent of connective tissue, is more labile from young animals than from older animals. There is also the possibility that the collagen in these fish from Arctic waters could be more heat labile than those from warmer waters and thus make them more susceptible to softening and gaping. I have found the shrinkage temperature of Newfoundland cod skin to be about 35°C (95°F), as compared with 39° to 40°C (102° to 104°F) for cod caught off Aberdeen.

From my observations, there appears to be one advantage for these fish when they are frozen into blocks of trimmed fillets. Because of their softness, the fish mould well. The frozen blocks are almost perfect geometrically, have no voids and are thus excellent for sawing into portions with minimum wastage.

Banks (U.K.): I would like to correct a statement by Love, in which he claims that he has been told that cod in good condition do not gape when frozen. A lot depends on what is meant by good condition. With fish in which roes and milts are well developed, which I would consider to be in good condition, there is little or no gaping. When the fish are feeding heavily shortly after spawning, there can be considerable gaping as Love says. Such fish are well known in the trade, even when iced, as soft fish. This is also true with herring for instance. Indeed the so-called "feedy" herring has been known for many years as soft fish, difficult to fillet, to kipper and to freeze.

Burt (U.K.): I should like to describe the results of some of our experiments at Torry that appear to complement those of Kelly in which he investigated the effects of bleeding immediately after the fish were landed on deck. As was mentioned in Jones' review, delay before gutting—or before any other bleeding procedure is started—has a marked effect on the extent of discolouration present in sea-frozen fillets. Working with cod, haddock and hake, we have observed on very many occasions that increasing delays before gutting lead to increasing amounts of blood discolouration for only a comparatively short period. After that period has passed, the eventual colour of the fillets actually improves. The worst colour was associated with pre-gutting delays of about 4 h if the catch had been held at chill temperatures and at about 1 or 2 h if they had been held at 13° to 15°C (55° to 59°F). After 8 h or so the colour of the fillets appeared to become acceptable again. In most of these cases, holding the gutted fish for a "bleeding" period did improve the colour of the fillets although bleeding times of more than 40 min led to no further improvement in colour and often 20 min produced the maximum effect. At chill temperatures, gutting was found to be as efficient as throat and/or tail cutting for bringing about bleeding. At higher temperatures, gutting was not such a good procedure as the others.

Another rather significant finding was that the blood in most of the cod and haddock used was still fluid even 20 h after capture—it had not coagulated in the blood vessels of the intact fish. The clotting time of samples of blood taken from these fish at first increased with delay after death and then decreased again. The longest clotting times were associated with poorest fillet colour.

Little (U.K.): The fishing industry is going through a period of change and this change is reflected in the difficulties expressed by fish technologists in getting their quality control procedures adopted on board the freezing trawler. There is a schism between the requirements of buyer and the aim of the trawler captain. The trawler captain's aim is to catch and land as much fish as possible; quality must be secondary. We must remember that we are now producing food factories instead of just catching vessels—in this respect we must treat a floating factory in the same way as one on land, i.e. throughput must be controlled to produce the product most desirable to the purchaser. This quality has been shown to be dependent upon such factors as time of processing, bleeding, temperature control and fishing ground. Obviously these factors cannot be given proper consideration under the present conditions of heavy fishing. To effect good quality control it would be necessary to: (a) have a quality controller on board who could control the fishing rate and (b) pay the crew a share in terms of quality and not quantity.

A second point is that, in considering freezing cod *pre-rigor*, it must be remembered that large quantities of fillets are manufactured into blocks at sea. Most of these blocks are subsequently cut into individual portions which are usually cooked from the frozen state. We have found that portions from such blocks made from *pre-rigor* fillets are very susceptible to "*rigor-caloris*" or heat-accelerated *rigor*. This causes the portions to distort badly, have large cooking losses and to be generally unsatisfactory. Much better results were obtained from *in-rigor* and *post-rigor* fish. Of course, this trouble could be offset by prolonged storage at −23°C (−11°F) or short-term stage at −5°C (23°F) but this would involve extra handling.

Jones (U.K.): This of course is a very pertinent comment that Little has made. I well remember about six years ago when I first started work on this sort of thing and had come across this phenomenon of break-up in the context of accelerated *rigor*, and some discolouration effects, putting it to a trawler owner that he might perhaps consider restricting his catching rates. I shudder now to think of the look I had from him. With regard to the ill effect of thaw *rigor* that Little has found in fish finger production and cooking, I was wondering whether perhaps one had to consider long-term storage or whether one couldn't simply raise the storage temperature. This probably has to be done anyway if the blocks are going to be sawn economically and I wonder whether it may well be more economic to take it up to a temperature that overcomes this effect and then perhaps lower it again. For instance, Cape hake can, on occasion, be improved by this sort of procedure—the object being to toughen it up a little. One can toughen up without paying too much of a penalty in flavour change. It's a matter of striking the right balance here.

Heen (Norway): May I add that 25 years ago a study was made on this point by H. Larsson and he arrived at the conclusion that cod stored at −17°C (1°F) will show the glycogenolysis restarting after thawing if storage is limited to two months. If the storage at −17°C (1°F) is extended beyond two months then it seems that the mechanism of glycogenolysis is denatured. If you use this effect as a control, factors of temperature and time will both have to be considered.

Design of Systems for Freezing Tuna at Sea

by J. W. Slavin and R. Finch

Design of systems for freezing tuna at sea

This report discusses some of the basic equipment design considerations in freezing tuna in brine or in circulating air and attempts to evaluate the pros and cons of freezing systems which involve (1) freezing in brine or in air in the hold or (2) freezing in the 'tween-deck area with brine or air and transfer to the frozen storage hold.

Dispositifs pour la congélation du thon a bord des navires

La communication étudie certains aspects du dessin des matériels de base pour la congélation du thon en saumure ou par circulation d'air, et s'efforce d'évaluer les avantages et les inconvénients des dispositifs de congélation prévoyant: (1) la congélation en saumure ou par courant d'air dans la cale; ou (2) la congélation, en saumure ou par air forcé, dans l'entrepont, suivie du transfert en cale de conservation.

Proyecto de sistemas de congelación de atún a bordo

Este informe examina algunas de las consideraciones fundamentales sobre el proyecto del equipo para congelar a bordo atún en salmuera o en aire en circulación y trata de evaluar los pros y los contras de los sistemas de congelación que implican (1) la congelación en salmuera o en aire en la bodega, o (2) la congelación en el entrepuente con salmuera o aire y el transporte del producto a la bodega frigorífica.

Immersion freezing

IN the late 1800s refrigeration engineers pioneering development of the food freezing industry became intensely interested in immersion cooling because of the simplicity of the method and the rapid heat transfer. Systems used varied from rather crude batch-type devices, using propellors or pumps to ensure adequate circulation of the freezing medium, to continuous conveyor-type equipment employing spray or immersion to accomplish the freezing. Except for some experimentation, the freezing medium was limited to sodium chloride brine because of its non-toxic properties, low cost and ready availability.

In the early days of food freezing, fish and fishery products received special attention because of their high perishability in the unfrozen state. In fact, a number of brine cooling and freezing systems were designed exclusively to freeze whole fish, fish fillets, shellfish and other seafood items.

In recent years with development of rather sophisticated methods of packaging and marketing foods, immersion freezing systems have been, for the most part, replaced by more convenient, packaged types of equipment using multi-contact plates or circulating air to achieve the necessary freezing. With the exception of cryogenic refrigerants, such as liquid nitrogen or carbon dioxide, immersion or spray freezing of food is primarily limited to fish and poultry. Immersion freezing of poultry is used primarily to set a white colour on the skin of the bird.

Immersion freezing is particularly well suited to freezing fish and shellfish at sea. This is because of the simplicity and compactness of the equipment and ease in which whole fish and shellfish of widely varying physical characteristics can be handled. Immersion freezing has been used successfully to freeze tuna, salmon, halibut, groundfish, such as haddock and cod, and shellfish, such as shrimp and scallops, but has only been applied commercially on a large scale to tuna, approximately 155,000 t of tuna being frozen annually aboard U.S. fishing vessels.

Brine freezing tuna at sea

Tuna was first frozen at sea in the early 1930s to solve the problem of spoilage, which became acute as the increasing demand by west coast canneries led to further and longer trips. The first freezing equipment was based largely upon work carried out at the Hooper Foundation in San Francisco and comprised a system of brine freezing in wells similar to that in wide use today. The rapid cooling of the tuna was originally ensured by the circulation of the brine through pack ice, but this valuable feature has long since been discontinued. Various forms of brine spray cooling have been installed on some seiners; this being the most economical way to convert open-hold ice vessels to brine freezing.

At best present tuna boat refrigeration performs reasonably well; at worst it is inadequate. As a result there are considerable losses of fish from spoilage annually, variously estimated to run from 2 to 5 per cent of landings. Even the smaller figure represents a direct annual loss of nearly a million dollars, based on an annual catch by the U.S. fleet valued at $44.6 million (Lyles, 1966). When the freezing of a particular lot of fish is inadequate, part of the load may be rejected as a result of bacterial spoilage, but this is not the only loss. The quality of the remaining material is often lowered to some extent, so that the final canned tuna produced may be worth considerably less to the canner.

While it is impossible to estimate accurately the total loss to both the fisherman and the canner of inefficient refrigeration, it probably amounts to a good deal more than a million dollars annually.

Clearly then, the proper design and operation of freezing equipment on tuna boats is of considerable economic importance. With the recent amendment of the United States Fishing Fleet Improvement Act to provide for a construction differential subsidy, there has been an upsurge of activity in design and building of fishing vessels. To qualify, a vessel must be, in terms of the act, ". . . of advanced design which will enable it to operate in expanded areas, and be equipped with newly developed gear . . .". In particular, much interest has developed in the design of alternative systems for freezing tuna.

The purpose of this report is:

(1) To examine some of the important factors which should be considered in designing a refrigeration system on a specific vessel.

(2) To apply these to an analysis of different refrigeration and handling methods for use on new vessels.

BASIC DESIGN CONSIDERATIONS

There are a number of factors which affect the requirements for freezing tuna at sea. Three of these distinguish the tuna seine fishery from almost all others. These are the big hauls which may be made at any one time, the great size of the larger fish with the corresponding slow heat removal and, in the case of the tropical tunas, the high temperatures of the landed fish.

A system suitable for freezing tuna must be designed to take account of these factors and in addition meet other general requirements. Physically it must be reliable and adequately designed to enable large quantities of tuna to be moved in and out in a short time. It must be compact, accessible for service, and compatible with the other space, weight and trim requirements of the vessel. The cost of installation and maintenance must be low enough to permit an adequate return on the investment. Finally, in terms of performance, the system must be able to chill, hold, freeze, store and thaw tuna under conditions which will assure high quality when delivered to the cannery. Some of these factors are now considered in more detail.

Vessel

(1) Type of gear: purse-seining is likely to be the catch method which will dominate the eastern Pacific tuna fishery in the foreseeable future.

(2) Fish capacity: the vessel capacity may vary from 400 to 900 t of fish.

(3) Maximum storage density: for tuna in brine wells this is approximately 800 kg/m^3 (50 lb/ft^3). Maximum storage density for tuna in dry refrigerated hold is approximately 575 kg/m^3 (36 lb/ft^3).

(4) Refrigeration capacity needed to freeze fish from 21°C (70°F) to −18°C (0°F) in 24 h, and to store the frozen fish at −18°C (0°F) in dry well.

Operational

(1) Range: vessels can range several thousands of miles and may be required to hold fish for 12 weeks or more, although the average trip time is nearer six to eight weeks.

(2) Catch rate: the average catch rate has varied from 1960 to 1966 from 5.3 t to 7.8 t per 24 h fishing time. However, the variation is considerable. A better idea is given by the weight of fish caught in large sets as shown in table 1. This in itself is not a maximum since more than one set may be made in 24 h.

(3) Fish size: tuna landed for canning by the U.S. purse-seine fleet vary in size from 2.3 to 59 kg (5 to 130 lb). The size distribution shows that some 20 per cent of the yellowfin are in the weight range 12 to 59 kg (26 to 130 lb). The cross sectional dimensions of these tunas at the point of greatest girth is approximately 18 cm (7 in) for 12 kg (26 lb) fish and 33 cm (13 in) for 59 kg (130 lb) fish.

(4) Fish and sea surface temperatures: tropical tunas are fished in waters up to 30°C (85°F). The temperatures of the landed fish are higher, reaching as much as 32°C (90°F).

(5) Required rate of unloading fish from the vessel: 200 to 400 t/day.

TABLE 1. DATA ON TUNA SETS
(Inter-American Tropical Tuna Commission)

	1962		1963		1964	
	† Sets %	‡ Tuna %	† Sets %	‡ Tuna %	† Sets %	‡ Tuna %
Sets under 10 t	53.5	15.7	52.6	14.2	55.6	17.2
Sets 10 to 99 t	46.1	80.6	47.7	80.3	43.7	76.4
Sets over 99 t	0.4	3.7	0.7	5.5	0.7	6.4

* All figures refer only to successful sets.
† Sets in group as percentage of all sets for year.
‡ Tonnage of tuna caught in group as percentage of all tuna seined for year.

Rate of freezing

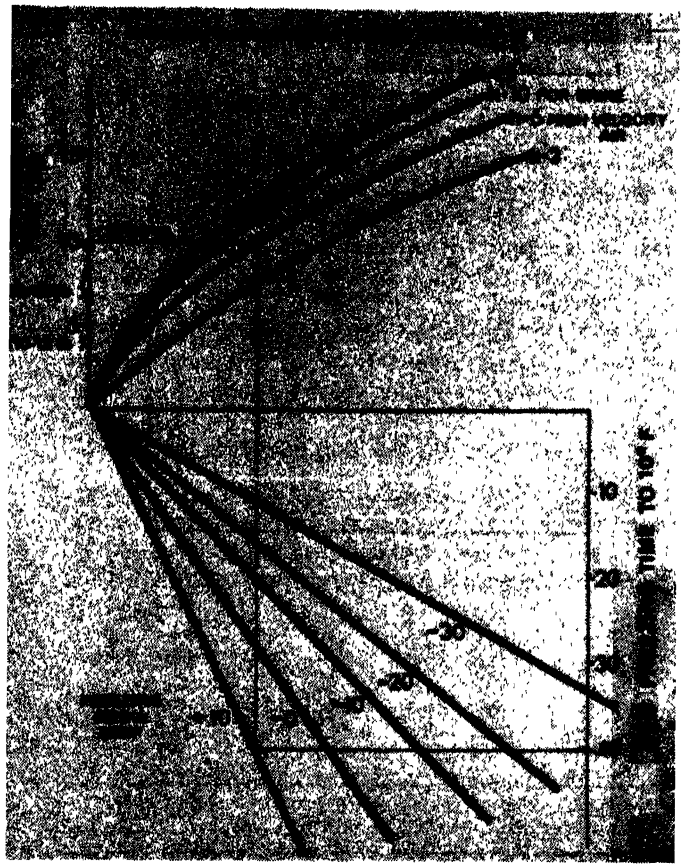
Information on the time required to freeze tuna of different sizes is shown in fig 1. The use of a nomogram of this type was discussed previously by Slavin (1964).

Since the rate of freezing affects handling capacity, it must be given serious consideration. When comparing freezing in brine with freezing in air, it can generally be assumed that if similar temperatures are used and brine circulation is adequate, the product will freeze about 20 to 30 per cent faster in brine than it will in the circulating air. It is interesting to note that comparable freezing rates can be attained with brine and air by manipulation of the freezing medium temperature and air velocity.

Quality aspects

Not enough is known about the effects of different freezing rates on the ultimate quality of tuna after canning. It seems likely that quality considerations are more important in immersion freezing than in freezing in circulating air because of the adverse effects that result from penetration of freezing media into the whole fish. With brine freezing, salt penetration increases (1) with an increase in period of immersion, temperature of freezing medium and brine concentration; and (2) with a decrease in the size of the fish. The exact effect of rate of freezing on quality for a given immersion period is not known, but it is believed that with faster freezing less salt penetration will occur.

In air-blast freezing severe dehydration can occur during long freezing periods. Thus, as with sodium chloride brine, we recommend a maximum freezing time of 24 h for air-blast freezing. To keep desiccation at a



5 in< >12.5 cm
10 in< >25.5 cm
15 in< >38.0 cm

10°F< > −12°C
0°F< > −18°C
−10°F< > −23°C
−20°F< > −29°C
−30°F< > −34.5°C

10–12 lb< > 5 kg
40–50 lb< >20 kg
70–80 lb< >35 kg

h = 1 Btu/h ft² °F< > 4·88 kcal/h m² °C
h = 15 Btu/h ft² °F< >73 kcal/h m² °C
h = 10 Btu/h ft² °F< >49 kcal/h m² °C
h = 6 Btu/h ft² °F< >29 kcal/h m² °C
h = 3 Btu/h ft² °F< >14·5 kcal/h m² °C

Fig 1. Nomogram for freezing whole tuna of various sizes

minimum, the fish should be glazed and stored at a temperature no higher than −18°C (0°F) after freezing.

Another immersion freezing medium that shows considerable promise is direct contact Refrigerant 12, which gives a very high heat rate of transfer. This method is so far only in the early stages of development and so its potential is not yet clear.

EVALUATION OF DIFFERENT FREEZING METHODS

Next in this report we will consider the use of different freezing methods on a large tuna seiner and their advantages and disadvantages relative to quality, versatility, vessel productivity and general handling efficiency. Since these methods, except for the present one, represent freezing systems which have not been subject to commercial appraisal, our evaluation is somewhat subjective. It is hoped that a discussion of the various alternatives available will be helpful in arriving at a decision as to the best freezing system for the vessel involved. In this evaluation the present brine system is used as a basis of comparison.

Present brine freezing system

In this system fish are put into tanks containing chilled sea water. When the fish has reached −1° to 0°C (30° to 32°F) and the well is full, the sea water is fortified with salt to make up a 15 per cent circulating brine solution, which is cooled with ammonia refrigeration coils lining the inside of the tank and in turn extracts heat from the tuna. After the fish are frozen, the brine is pumped out and the fish remain stored in the well which is maintained at −7°C (20°F) or lower.

(1) Advantages

(a) handles the fish as quickly as they are taken on the vessel;
(b) low refrigeration horse power;
(c) high storage rate, 800 kg/m³ (50 lb/ft³);
(d) no rehandling at sea.

(2) Disadvantages

(a) low- or variable-quality fish;
(b) excessive time and labour in discharging at dock (three days);
(c) fish must be thawed to some extent to be unloaded;
(d) method not generally suitable for other fish.

Modify present brine system to improve heat transfer and to containerize the catch. In this proposed system (see fig 2) the fish hold is divided into narrow rectangular-shaped tanks, rather than the conventional square wells.

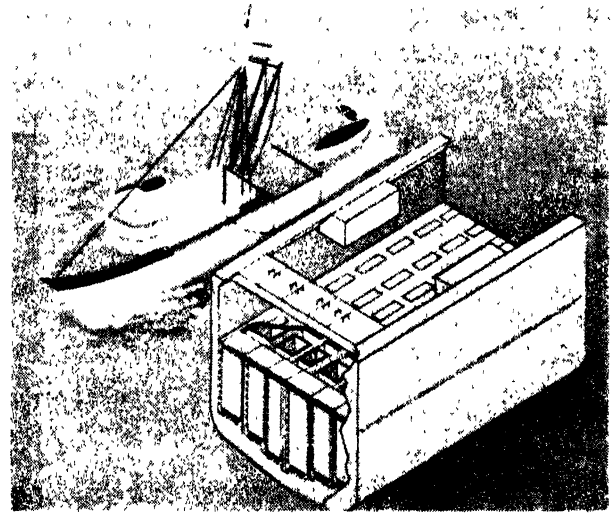


Fig 2. View of proposed containerized hold in a tuna vessel. Fish would be put into container through deck openings, chilled, then frozen

With tanks about 1 m (3 ft) wide heat transfer is improved considerably. Also, some degree of containerization is possible because of the longitudinal tanks in which containers can be moved and unloaded at one end.

(1) Types of improvements.
  (a) Improve heat transfer:
    (1) add bigger pumps;
    (2) add external heat exchangers;
    (3) increase refrigeration capacity;
    (4) add heat in thawing.

(b) Containerize fish:
(1) redesign tanks so that fish can be loaded into wire-mesh containers, frozen in brine in the containers and then unloaded in the containers;
(2) Cool the fish with brine spray; then freeze by immersion.

(2) Comparison of modified system with present brine system:
(a) increased heat transfer will decrease the freezing time and result in a significant improvement in product quality. However, this improvement may not be as great as when using forced air circulation;
(b) modification of tank design so as to permit containerization of the fish would overcome the present disadvantage of excessive time in unloading fish at the dock and, in fact, the fish could be unloaded without complete thawing and transferred to freezer storage;
(c) with both improved heat transfer and redesign of the tanks so as to permit containerization of the fish, the brine-freezing system would offer many advantages in freezing tuna.

Freeze in brine freezers located in the 'tween-deck area: then transfer and store fish in dry hold

(1) Batch freezing (fixed rate).
(a) Advantages over present brine system:
(1) better quality (more uniform and faster freezing, less salt, lower temperature);
(2) no thawing needed prior to unloading;
(3) quicker unloading;
(4) more versatility for freezing other products,
(b) Disadvantages over present brine system:
(1) more handling on the vessel;
(2) reduction of fish-carrying capacity by 20 to 30 per cent;
(3) freezing capacity influenced greatly by gluts.

(2) Continuous brine freezing.
(a) Advantages over present brine system:
Same as for batch-brine, except that handling would be less.
(b) Disadvantages over present brine system:
Same as for batch-brine, except there would be less control of immersion period to suit size of big and small fish. Long freezing time required for big fish would lead to excessive capacity.

Freeze in blast-air freezers located in the 'tween-deck area: then transfer and store fish in dry hold

(1) Batch freezing.
(a) Advantages over present brine system:
(1) improved quality;
(2) ease of unloading;
(3) greater versatility and flexibility in handling species other than tuna;
(4) no need for thawing prior to unloading;
(5) good potential for mechanization (use of conveyors, etc.).
(b) Disadvantages over present brine system:
(1) more handling on the vessel (labour for transfer of fish to freezer and then from freezer to hold);
(2) need chilled (RSW) buffer storage space to hold fish prior to freezing;
(3) less carrying capacity due to lower packing density. Load will be reduced by 25 to 35 per cent depending on ability to utilize between-deck area and salt-storage space for fish storage;
(4) higher cost:
(i) initial capital expenditure for equipment;
(ii) horse-power requirements would be about 55 per cent higher.

(2) Continuous air freezing.
(a) Advantages over present brine system:
Essentially the advantages, when compared with the present brine system, would be the same as those of batch air freezing. However, with the continuous system, handling on the vessel would be slightly less than with batch air freezing, and space utilization would be more efficient.
(b) Disadvantages over present brine system:
Essentially disadvantages would be the same as those of the batch air system, except that the continuous air freezing system would be somewhat more expensive than the batch air and difficult to contemplate with large fish.

Air freezing bulk fish in dry hold

There are two concepts of interest: (1) freeze the fish in containers in the hold, and (2) freeze the fish without the containers but instead stacked in fish pens in the hold.

Freeze the fish in containers in the hold

(1) Advantages over present brine system:
(a) the fish could be unloaded much faster;
(b) fish would not have to be thawed prior to unloading.

(2) Disadvantages over present brine system:
(a) extremely slow freezing may have adverse effect on product quality;
(b) storage density would be lower than in any other system, probably less than 480 kg of fish per m^3 (30 lb/ft^3);
(c) mechanical systems would have to be set up for handling the containers.

Freeze the fish in the hold in bulk without containers

(1) Advantages over present brine system:
Storage density would be approximately the same as that of present brine system; may be able to increase storage capacity by 10 per cent by utilizing between-deck area for storage.

TABLE 2. RATING OF TUNA FREEZING METHODS

(Based on score of 0 to 10 for each attribute with 10 the highest)

Freezing method	*High quality*	*Little handling on vessel*	*High versatility*	*High carrying capacity*	*Rapid and easy unloading*	*Initial low cost*	*Total score*
(A) Present brine system	4	10	0	10	2	8	34
(B) Modify present brine system to improve heat transfer and to containerize	7	10	5	9	10	6	47
(C) Freeze in brine in 'tween deck freezers and store in dry hold							
Batch	7	4	6	6	5	5	33
Continuous	5	6	5	6	5	5	32
(D) Freeze in hold in brine spray	2	9	0	10	4	9	34
(E) Freeze in blast air freezers and store in dry hold							
Batch	10	4	10	5	5	4	38
Continuous	10	6	10	5	5	3	39
(F) Air freeze bulk fish in hold							
In containers	4	8	0	3	9	5	29
Stacked in pens	4	6	0	9	3	6	28

(2) Disadvantages over present brine system:

(a) Essentially the disadvantages would be the same as those of freezing in containers, except for the addition of another disadvantage—that of increased time and difficulty in unloading the vessel.

(b) Thawing the fish in circulating air may also present serious problems.

CONCLUSION

Our comparison of the different freezing systems shows that some freezing systems are better suited to certain operations than are others. The final decision must be based on the relative importance to the operator of such factors as quality, ease of handling on the vessel, versatility, speed in unloading and carrying capacity. Initial cost may be a governing factor too, but this should not be the limiting factor, for it is rather basic to pay more for something better.

An evaluation of the different freezing methods is given in table 2 of this report. Each system was rated by assigning a score of one to ten for each attribute of importance, with 10 representing the best rating. This, of course, is somewhat arbitrary and it is recognized the ratings might vary somewhat with individual operations and raters.

Air-freezing systems do offer greater versatility than do brine systems and even with the loss of capacity and increased handling their use should be considered if the vessel is to be used for handling a wide range of fish and shellfish. On the other hand, if the vessel is to be used primarily for tuna we favour immersion freezing because of ease in handling and high storage capacity. We feel the disadvantages of the present brine system can be overcome to permit less rejects for quality, to permit some diversification, and to permit much faster unloading, without the need for complete thawing.

Our recommendations are as follows:

(1) If the vessel is to be used for freezing tuna at least 50 per cent of the time

We believe that an improved brine freezing system involving better heat transfer and containerization of the fish to increase unloading rate and to permit unloading of the tuna without thawing offers the most advantages. With the addition of external heat exchangers and increase in brine circulation, control of stowage density to about 800 kg/m^3 (50 lb/ft^3) and increase of refrigeration capacity to permit freezing of not less than 1.5 t fish/h, it will be possible to reduce freezing time considerably and improve product quality. Reorientation of the brine tanks and installation of removable inner stowage tanks will permit rapid unloading of the catch, with retention of high storage density. Also, we feel that this system might be used for freezing salmon and halibut.

(2) If the vessel is to be used for freezing tuna less than 50 per cent of the time and is to have a great deal of versatility for freezing king crab, groundfish and other fish and shellfish

We would suggest using a continuous air-blast freezing system rather than the brine. We feel the increased versatility of the former would offset the additional cost and space requirements, which may run 25 to 35 per cent more but might be offset in part by heading the fish. In the continuous air system the fish would be frozen in the 'tween-deck areas on conveyors using a 7 h freezing cycle. Equipment would be designed to handle about 1.5 t of fish/h. After freezing, the frozen product would be hand-stacked in the dry refrigerated hold of the vessel. We estimate the continuous freezing conveyor would hold about 10 t of fish. Those fish taken on board in excess of the conveyor stowage requirements would have to be stored in the 'tween-deck area and cooled with sprayed refrigerated seawater until loaded into the conveyor.

References

LYLES, C H 1966 Fishery Statistics of the United States CFS 4400, U.S. Department of the Interior, Bureau of Commercial Fisheries.

SLAVIN, J W 1964 Freezing seafood now and in the future. *ASHRAE Jl*, May.

La congélation du poisson par immersion dans une saumure de chlorure de calcium

par P. Dalcq

La congélation du poisson par immersion dans une saumure de chlorure de calcium

La congélation du poisson par immersion dans un liquide réfrigéré est beaucoup plus rapide que la congélation dans un tunnel à air froid ou dans un congélateur à plaques. Elle n'exige qu'un matériel peu coûteux et est simple à conduire, tout en permettant des capacités de production élevées avec une installation assez modeste.

Parmi les fluides frigorifères bon marché, les solutions de chlorure de calcium semblent très intéressantes, vu leur bas point cryohydratique (−51°C; −60°F) et leur faible viscosité. Elles permettent une congélation bien plus rapide et à température beaucoup plus basse que les saumures à base de chlorure de sodium ou sel ordinaire, d'où rendement et capacité accrus de l'installation.

On relate des essais de laboratoire ayant pour but de comparer les saumures de chlorure de calcium, seul et additionné de glucose, et les saumures de chlorure de sodium, avec comme témoin la congélation dans l'air froid.

Les poissons congelés ont fait l'objet de dosages de Cl^- et de Ca^{++}, puis d'analyses organoleptiques. Il en résulte que la congélation dans les saumures de $CaCl_2$ seul n'altère ni l'odeur, ni la consistance, ni le goût du poisson cuit mais fragilise peut-être sa peau. Cet inconvénient, s'il se confirme, semble en tout cas éliminé par l'addition de glucose au $CaCl_2$, mais celle-ci conduit à une augmentation du prix de la saumure qui, à part cela, ne présente aucun avantage sur la solution de $CaCl_2$ seul.

Fish freezing by immersion in calcium chloride brine

Freezing of fish by immersion in a chilled fluid is a far more rapid process than either the air-blast tunnel or plate freezing method. The equipment required is inexpensive and easy to operate, and yet high production capacities are possible with installations of no great size.

Among the cheaper refrigerants calcium chloride solutions seem to offer considerable advantages, because of their low cryohydric point (−51°C; −60°F) and low viscosity. They allow a much faster freezing, at considerably lower temperatures, than sodium chloride (common salt) brines, thus improving plant capacity and performance.

Comparative laboratory trials made on calcium chloride brines, with or without the addition of glucose, and sodium chloride brines, using air-blast freezing as the control, are described. Frozen fish were tested for Cl^- and Ca^{++} and examined organoleptically. It was found that freezing in pure $CaCl_2$ brine does not impair the odour, texture, or flavour, although it apparently renders the skin more fragile. Seemingly, this last-mentioned drawback (if it is confirmed) can be avoided by the addition of glucose to the $CaCl_2$. However, this expedient raises the cost of the brine and except for protecting the skin offers no advantage over using pure $CaCl_2$.

La congelación del pescado por inmersión en salmuera de cloruro de calcio

La congelación del pescado por inmersión en un líquido refrigerado es mucho más rápida que la congelación en un túnel de aire frío o en una congeladora de placas. Exige un material poco costoso y muy sencillo de manejar, permitiendo obtener una producción elevada con una instalación bastante modesta.

Entre los líquidos de refrigeración baratos parecen muy interesantes las soluciones de cloruro de calcio, a causa de su bajo punto criohidrático (−51°C; −60°F) y de su escasa viscosidad. Permiten una congelación mucho más rápida y a temperatura mucho más baja que las salmueras a base de cloruro de sodio o sal común, y por lo tanto un mayor rendimiento y una mayor capacidad de la instalación.

Se describen ensayos de laboratorio realizados con objeto de comparar las salmueras de cloruro de calcio, solo y con glucosa, y las salmueras de cloruro de sodio utilizando como testigo la congelación en aire frío.

Al pescado congelado se le ha sometido a dosis de Cl^- y de Ca^{++} y posteriormente a análisis organolépticos. El resultado es que la congelación en salmueras de $CaCl_2$ solo, no altera el olor, la consistencia ni el sabor del pescado cocido, aunque quizás hace más frágil su piel. Este inconveniente, en caso de confirmarse, parece que se puede eliminar añadiendo glucosa al $CaCl_2$, pero esto último encarece el precio de la salmuera, la cual, aparte de esto, no presenta ninguna ventaja respecto de la solución de $CaCl_2$ solo.

INTERET DE LA CONGELATION PAR IMMERSION

LA congélation du poisson à bord permet de ramener à terre un produit de haute qualité et se révèle avantageuse aussi bien pour l'armateur que pour l'acheteur en gros, le détaillant et le consommateur. Au cours de ces dernières années ont été mises au point différentes méthodes de congélation du poisson en vrac, dont:

la congélation en tunnel d'air froid;
la congélation dans des armoires à plaques;
la congélation par immersion dans une saumure réfrigérée.

Cette dernière technique assure une transmission particulièrement rapide du froid au produit à congeler grâce au contact intime et à la grande différence de température qui existent entre le poisson et le milieu réfrigérant. De plus, les saumures ont un coefficient de conduction thermique environ 10 fois plus grand que celui de l'air (Plank, 1960). Enfin la congélation par immersion permet une production élevée dans une installation modeste et peu coûteuse.

SAUMURES DE CHLORURE DE SODIUM (SEL ORDINAIRE)

Le chlorure de sodium ou sel ordinaire (NaCl) permet de constituer des saumures utilisables pour la congélation du poisson par immersion. Il impose cependant deux servitudes aux utilisateurs.

(1) La concentration maximum de la saumure compatible avec la pratique industrielle ne permet guère de

travailler à une température inférieure à −15°C (5°F). On sait en effet que la température la plus basse que peut atteindre une solution de sel sans cristalliser est de −21,1°C (−6°F), fig 1.

(2) La pénétration du sel dans la chair du poisson et les apports constants d'eau de mer adsorbée sur les poissons provoquent une dilution progressive de la saumure, ce qui oblige soit à en rajuster constamment la concentration soit à en élever progressivement la température pour empêcher la cristallisation. En pratique, la saumure de sel permet la congélation par immersion dans un intervalle de température allant de −15° à −12°C (5° à 10°F), tout en exigeant une surveillance constante de sa concentration.

Or, comme le montre le tableau 1 (Soudan, 1965), la durée de la congélation augmente avec une élévation de la température de la saumure et, de plus, ce phénomène se marque d'autant plus que l'épaisseur du poisson est plus forte.

Ceci montre l'intérêt de substituer au chlorure de sodium un sel permettant d'abaisser notablement la température de fonctionnement de l'installation. Tel est le cas du chlorure de calcium.

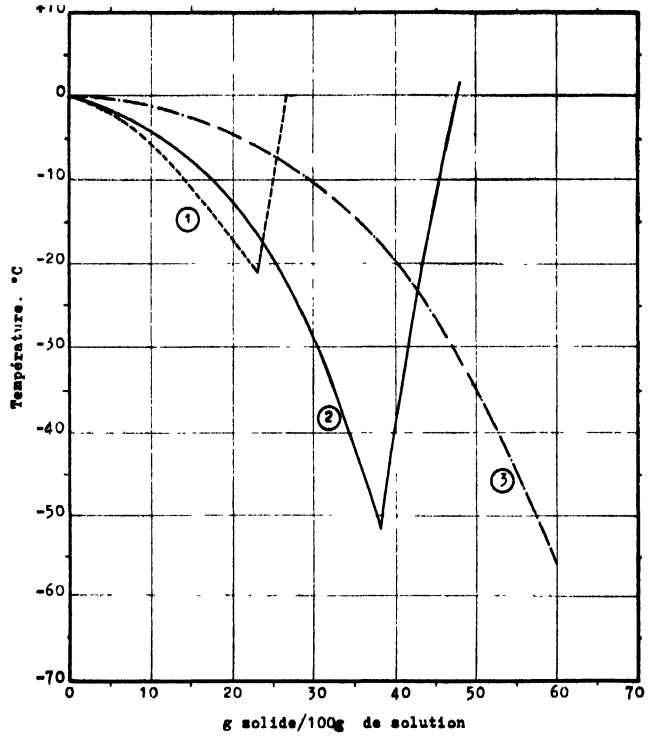
TABLEAU 1. DURÉES DE CONGÉLATION D'ÉGLEFINS (GADUS AEGLEFINUS) DANS UNE SAUMURE À 21 POUR CENT DE SEL (NaCl)

Epaisseur du poisson, cm	*Durée de congélation, min*	
	Saumure à −12°C	*Saumure à −18°C*
4	55	35
5	85	55
6,5	125	80
7,5	170	110
9	220	145
10	280	185

SAUMURES DE CHLORURE DE CALCIUM

Comme le montre la fig 1 (Mirroneau, 1962), une solution de sel ne peut descendre en dessous de −21,1°C (−6°F), tandis qu'une solution de chlorure de calcium permet d'atteindre la température minimum de −51,6°C (−61°F) sans formation de cristaux. Industriellement, une saumure contenant 38,3 pour cent de paillettes de chlorure de calcium (à 77 à 80 pour cent de $CaCl_2$) peut être utilisée jusqu'à −45°C (−49°F).

Toutefois certains auteurs, p. ex. Holston (1962), ont signalé que les saumures de $CaCl_2$ détérioraient la peau du poisson et que cet inconvénient pouvait être éliminé par l'emploi de saumures à base de glucose et de $CaCl_2$ dans la proportion 1 : 1 ou plus. C'est pourquoi nous avons déterminé expérimentalement la courbe de congélation des solutions contenant un mélange à poids égaux de paillettes de chlorure de calcium (à 77 à 80 pour cent de $CaCl_2$) et de glucose technique (fig 1). Comme on le voit, ce mélange permet d'atteindre une température de −56°C (−69°F) ou même inférieure, mais sa viscosité devient alors fort élevée pour une utilisation industrielle. Aussi convient-il de limiter la concentration en poids à maximum 30 pour cent de paillettes de chlorure de calcium et 30 pour cent de glucose technique, ce qui permet d'opérer industriellement à −50°C (−58°F), apparemment sans ennui dû à la viscosité.



1 Chlorure de sodium
2 Paillettes de chlorure de calcium à 77-80 % $CaCl_2$
3 Paillettes de chlorure de calcium à 77-80 % $CaCl_2$ et glucose technique dans le rapport pondéral 1 : 1

Fig 1. Courbes de solubilité dans les systèmes $NaCl$-H_2O; $CaCl_2$-H_2O; $CaCl_2$-Glucose-H_2O. (International Critical Tables, 1928)

AVANTAGES DES SAUMURES A BASE DE CHLORURE DE CALCIUM

La grande solubilité du chlorure de calcium, son point cryohydratique de −51,6°C (−71°F) et la faible viscosité de ses solutions permettent donc la congélation du poisson par immersion en un temps très court.

D'autre part, à concentrations égales, les saumures de $CaCl_2$ sont moins corrosives que celles de NaCl. De plus, la recherche de plus basses températures conduit à utiliser des solutions concentrées de chlorure de calcium, où l'oxygène est moins soluble et qui sont donc encore moins corrosives.

Un autre avantage des saumures à base de $CaCl_2$ est que, grâce aux très basses températures qu'elles atteignent, elles constituent un important volant de froid. Un volume déterminé de saumure peut donc congeler une quantité plus importante de poissons que le même volume de saumure à base de sel (NaCl). Cette propriété des saumures de chlorure de calcium est mise à profit lorqu'elles doivent absorber des quantités anormales de poissons, par exemple en cas de pêche surabondante.

Enfin, le poisson, mis en contact avec une saumure à −45°C (−49°F) se congèle à cœur en un temps très bref ainsi qu'il ressort du tableau 2 (Holston, 1962).

Le poisson devra donc séjourner moins longtemps dans une saumure de $CaCl_2$. Il en résultera une augmentation de la capacité de l'installation de réfrigération, si du moins on prévoit un apport suffisant de frigories. Inversement, pour traiter une quantité déterminée de poisson, on pourra utiliser une installation de réfrigéra-

TABLEAU 2. INFLUENCE DE LA TEMPÉRATURE DE LA SAUMURE SUR LA DURÉE DE CONGÉLATION DU POISSON

Eglefins		*Durée de congélation, min*		
Poids, kg	*Epaisseur maximum, cm*	*Saumure non agitée de $CaCl_2$ (25%) —glucose (25%) à −27,8°C*	*Saumure agitée de sel à 21% à −18°C*	*à −12°C*
1,4	6,5 env.	40 à 45	80	125
2,3	7,5 env.	90	110	170

tion plus petite, donc moins coûteuse, et un volume plus faible de saumure si celle-ci est à base de $CaCl_2$. Et malgré cela on absorbera plus facilement les à-coups de production qu'en cas d'emploi de saumure de sel ordinaire.

PARTIE EXPERIMENTALE

Nous avons effectué en nos laboratoires des essais d'orientation dans le but de comparer les saumures de chlorure de calcium, de chlorure de calcium plus glucose technique et de chlorure de sodium (sel) sous les points de vue suivants:

(1) Vitesse de congélation du poisson par immersion.

(2) Degré de pénétration des constituants des saumures dans la peau et la chair du poisson.

(3) Influence des saumures sur l'aspect et les propriétés organoleptiques du poisson.

Modes opératoires

Saumures utilisées. Les données relatives aux trois saumures utilisées et à l'air pulsé (essai témoin aux points de vue chimique et organoleptique) sont rassemblées dans le tableau 3.

Poissons utilisés. L'essai de congélation dans les différents milieux a été réalisé chaque fois sur trois cabillauds (*Gadus callarias*). Voici les caractéristiques des douze cabillauds utilisés.

(1) Longueur: 51 à 55 cm.

(2) Epaisseur maximum: 5,5 à 7 cm.

(3) Poids: 1,210 à 1,475 kg.

Ces petits cabillauds avaient été achetés à la minque de Zeebrugge et avaient été pêchés dans les 48 h précédentes. Ils étaient éviscérés.

Préparation des poissons avant congélation. Comme la congélation en mer se pratique fréquemment sur poissons intacts (non éviscérés), l'ouverture ventrale de nos cabillauds a été refermée par couture (figs 3, 4 et 5).

Pour chaque essai deux poissons ont servi aux analyses chimiques et organoleptiques, tandis que le troisième était destiné au contrôle de la température à cœur au cours de la congélation. Pour suivre l'évolution de cette température, on a introduit un thermocouple, avec gaine en porcelaine (isolant thermique), en biais au centre du poisson de manière que la soudure soit proche de l'arête centrale (figs 3, 4 et 5).

Les poissons ainsi préparés ont été conservés avant congélation à la température de 1,5°C (35°F).

Congélation. La température au cœur des poissons et celle de la saumure ont été enregistrées et les résultats obtenus en fonction du temps sont portés à la fig 2.

On constate que la température des saumures, spécialement de celles qui contenaient du chlorure de calcium, s'est élevée rapidement dans les 20 premières minutes après l'introduction des poissons. Ceci est dû au fait que nous ne disposions pas d'une machine frigorifique suffisamment puissante pour compenser les pertes en frigories. En pratique, dans une installation bien dimensionnée, la température se maintiendrait sans changement notable, ce qui veut dire que −18°C (0°F), ou même moins, seraient atteints dans le poisson en un temps nettement inférieur aux 80 et 50 min qui furent nécessaires lors de nos modestes essais d'orientation, respectivement dans la saumure de $CaCl_2$ seul et de $CaCl_2$ plus glucose.

Dans les trois essais, les poissons ont été retirés de la saumure au bout d'1 h 30; puis ils ont été examinés visuellement et photographiés (figs 3, 4 et 5).

Ils ont alors été rincés rapidement à l'eau de ville pour éliminer l'excès de saumure, sans quoi les dosages dans la peau auraient été totalement faussés du fait des variations inévitables dans le degré d'égouttage. Ils ont été essuyés puis placés chacun dans un sac plastique durant 24 h en chambre froide à −20°C.

Prélèvement des échantillons pour analyses. En vue du prélèvement des échantillons on a procédé rapidement, pour éviter tout dégel des poissons, aux opérations de découpage suivantes (fig 6):

(1) Découpage, perpendiculairement à l'arête centrale et à partir de 5 cm environ en arrière de l'ouïe, d'une tranche de 5 cm d'épaisseur.

TABLEAU 3. MILIEUX EXPÉRIMENTAUX DE CONGÉLATION

	$CaCl_2$	*Saumure de $CaCl_2$ + glucose*	*NaCl (sel)*	*Air pulsé (poisson en sac plastique fermé)*
Composition, kg/100 kg	$CaCl_2$ 77–80: 37,5 Eau de ville: 62,5	$CaCl_2$ 77–80: 30 Glucose techn.: 30 Eau de ville: 40	Sel: 23 Eau de ville: 77	
Température initiale, °C	−45	−50	−15	−15 à −18
Température atteinte au coeur des poissons, °C	−18	−18	−10	−9,5
Temps pris pour atteindre cette température	80 min	50 min	85 min	18 h
Rapport $\frac{\text{poids saumure}}{\text{poids poissons}}$	5,2	5,5	5,25	—

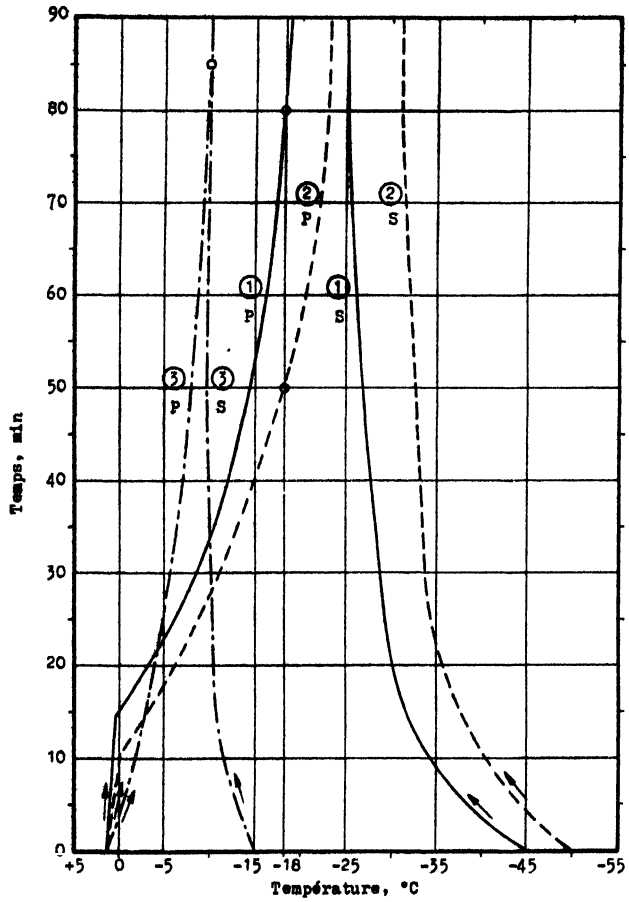


Fig 2. Essais de congélation—évolution deala température des saumures et au coeur des poissons

(2) Elimination de la moitié ventrale (recousue et peut-être de ce fait non hermétique avec possibilité d'infiltration de saumure) de cette tranche par sciage parallèle à l'arête centrale, juste au-dessus d'elle.

(3) Dans la moitié dorsale de la tranche, découpage de couches concentriques parallèles à l'arête centrale, de façon à prélever la peau (couche 0) et trois couches de chair, chacune d'environ 1 cm d'épaisseur (couches 1, 2 et 3), la 3e étant le cœur dépourvu d'arête centrale.

Le reste du poisson, du côté de la queue, a été conservé en sac plastique à —20°C (—4°F) pour les essais organoleptiques, après en avoir éliminé la moitié ventrale comportant la fin de la zone recousue.

Analyses chimiques. Chaque prélèvement (quatre sur chacun des deux poissons de chaque essai) est pesé, puis broyé, puis soumis à une extraction à l'ébullition durant 30 min dans cinq fois son poids d'eau déminéralisée. Après filtration, on dose dans l'extrait aqueux:

(1) Les chlorures par titrimétrie VOLHARD, après décomposition des albumines par l'acide nitrique (AOAC, 1960).

(2) Le calcium par photométrie de flamme.

Fig 3. Cabillauds sortant de la saumure de $CaCl_2$ après congélation (non rincés)

Fig 4. Cabillauds sortant de la saumure de $CaCl_2$+glucose après congélation (non rincés)

Fig 5. Cabillauds sortant de la saumure de NaCl (sel) après congélation (non rincés)

Fig 6. Découpage du poisson en vue du prélèvement des échantillons pour analyses

Analyses organoleptiques. Celles-ci ont été effectuées par cinq spécialistes de la Station de Recherches pour la Pêche Maritime d'Ostende. Elles comprennent les appréciations suivantes:

(1) Consistance du poisson cru.

(2) Aspect du poisson cru.

(3) Aspect du poisson cuit à la vapeur, sans sel ni épices.

(4) Sur poisson cuit comme ci-dessus: odeur, consistance et goût, chacune de ces propriétés étant cotée

TABLEAU 4. RÉSULTATS DES ANALYSES CHIMIQUES ET ORGANOLEPTIQUES

Milieu	*Saumure de $CaCl_2$*		*Saumure de $CaCl_2$ + glucose*		*Saumure de NaCl (sel)*		*Air*	
Poisson	1	2	1	2	1	2	1	2
Teneur en Cl^-, g/kg								
Couche 0 (peau)	19,50	21,20	5,61	4,74	43,80	62,80	2,50	3,33
Couche 1 }	1,64	1,83	0,90	0,87	4,71	6,92	1,38	1,20
Couche 2 } (chair)	1,30	1,00	0,56	0,73	1,13	1,34	1,25	1,00
Couche 3 }	1,11	1,27	0,91	1,17	1,60	1,40	1,25	1,25
Teneur en Ca^{++}, g/kg								
Couche 0 (peau)	8,60	9,40	1,25	0,53	—	—	0,15	0,33
Couche 1 }	0,05	0,08	0,05	0,06	—	—	0,05	0,05
Couche 2 } (chair)	0,05	0,06	0,04	0,05	—	—	0,11	0,08
Couche 3 }	0,05	0,06	0,05	0,04	—	—	0,05	0,12
Poisson cru dégelé								
Consistance	Très molle		N (x)	± molle	N (x)	N (x)	N (x)	± molle
Aspect	Peau très abîmée, visqueuse		N (x)	Peau abîmée	N (x)	Peau abîmée	N (x)	N (x)
Poisson cuit								
Aspect	Défavorable		N (x)	Légèrt abîmé	N (x)	Légèrt abîmé	N (x)	N (x)
Odeur, /10	7	8	8	8	8	8	8	8
Consistance, /10	10	10	8	8	7	8	8	8
Goût, /10	9	9	8	8	8	8	8	8

(x) N = Normal(e).

sur un maximum de 10 correspondant à l'odeur, la consistance et le goût normaux des cabillauds considérés comme excellents.

Résultats

Les résultats des analyses chimiques et organoleptiques figurent au tableau 4.

Commentaires des résultats

La meilleure consistance du poisson cuit et le meilleur goût ont été obtenus suite à la congélation par la saumure de $CaCl_2$ seul. Peut-être les cinq dégustateurs ont-ils été favorablement influencés par le très léger goût de sel décelé sur ces poissons? En tous cas aucun des cinq n'a décelé le léger goût amer dont parle parfois la littérature.

L'aspect défavorable dû à la détérioration de la peau suite à la congélation dans la saumure de $CaCl_2$ seul constitue certes un inconvénient pour les poissons non destinés au filetage. Il est possible cependant que, nos laborants n'ayant pas été prévenus du fait qu'on apprécierait l'aspect du poisson, la détérioration soit due aux manipulations durant les opérations de sciage. Les laborants étaient en effet munis de gants en caoutchouc rugueux (antidérapant). Ont-ils dû particulièrement serrer le poisson pour le maintenir lors du découpage?

De toutes façons les dégradations de la peau disparaissent pratiquement lorsqu'on ajoute au $CaCl_2$ un poids égal de glucose dans la saumure. Cependant, comme le glucose ne fait rien gagner aux points de vue odeur, consistance et goût du poisson cuit, il y a lieu de se poser la question de son intérêt réel en regard de son coût élevé et de la complication qu'entraîne son emploi.

La peau se laisse incontestablement pénétrer par les ions Cl^- et Ca^{++} du $CaCl_2$ mais constitue une excellente barrière protectrice pour la chair sous-jacente dans laquelle on retrouve pratiquement la même quantité de Cl^-, que le poisson ait été congelé à l'air ou dans une saumure de $CaCl_2$ (seul ou additionné de glucose).

Par rapport au $CaCl_2$, le NaCl (sel) laisse pénétrer nettement plus de Cl^- dans la peau et dans la chair contiguë, sans que cela semble cependant avoir un effet grave sur le goût du poisson cuit.

CONCLUSIONS

Les saumures de chlorure de calcium—seul ou additionné de glucose—permettent de congeler le poisson par immersion à température beaucoup plus basse, et ce en un temps nettement plus court, que les saumures de chlorure de sodium (sel ordinaire).

Le chlorure de calcium seul n'altère ni l'odeur, ni la consistance, ni le goût du poisson cuit, mais il se pourrait qu'il abîme sa peau, ce qui lui donne un aspect défavorable constituant un handicap en case de non-filetage. L'addition de glucose au chlorure de calcium semble éliminer cet inconvénient, mais entraîne des dépenses supplémentaires, dont il y aurait lieu d'évaluer la rentabilité.

Il y aurait intérêt à compléter nos essais d'orientation par les déterminations suivantes:

(1) Aspect, odeur, consistance et goût du poisson congelé dans une saumure de $CaCl_2$, après six mois de stockage à −20°C (−4°F) en entrepôt frigorifique.

(2) Aptitude au filetage du poisson ainsi congelé, et après six mois de stockage.

(3) Rapidité de congélation dans une installation industrielle bien dimensionnée au point de vue apport de frigories.

(4) Intérêt d'une congélation à très basse température maintenue constante (−35° à −40°C).

Remerciement

In fine ce nous est un agréable devoir d'exprimer notre vive reconnaissance à la Station de recherches pour la pêche maritime d'Ostende, et en particulier à son ingénieur, Monsieur Vyncke, pour l'aide qu'ils nous ont apportée en appréciant organoleptiquement les résultats de nos essais.

Bibliographie

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS *J. Ass.* 1960 *off. agric. Chem.*, 9th ed., Section 18, Normes 18.008 et 18.009. (Methods of Analysis.)

HOLSTON, J A A new liquid medium for freezing round fish. 1962 *Comml Fish. Rev.*, Supplement 24(12), 36–40.

MIRONNEAU, L *Manuel du frigoriste*, Tome 1. 1962

NATIONAL RESEARCH COUNCIL OF THE U.S.A. *Int. crit. Tabl.*, 4. 1928

PLANK, R *Handbuch der Kältetechnik*, Tome 10, Springer-1960 Verlag, Berlin.

SOUDAN, FRANCE *La conservation par le froid des poissons,* 1965 *crustacés et mollusques*, Baillière et fils, Paris, pp. 377.

A Seagoing Fish Processing and Liquid Nitrogen Generation System

by F. Breyer, R. C. Wagner and J. Seliber

A seagoing fish processing and liquid nitrogen generation system

This report presents a plan for the processing and cryogenic freezing of fish fillets aboard a mother ship. The refrigerant, a cryogenic fluid (liquid nitrogen), is also generated aboard the mother ship. This method might be especially suitable for the developing nations, since it proposes utilization of existing small fishing vessels and provides flexibility of operation without high capital cost. The proposed fish factory ship is not a high-speed vessel but rather a mobile fish processing plant.

The possibility of incorporating a total energy power plant system is presented in this report. The economics of the plant, which has a 25 t/day capacity of frozen fillets, are also given. Use of fuel oil or liquefied natural gas in a gas turbine prime mover with utilization of waste heat is discussed.

Size of power units and cost of operation and the cost of liquid nitrogen are considered. The higher value fillets are individually quick frozen and lend themselves well to export sales. By-products of frozen fillet blocks, fish meal, or fish protein concentrate are also products for export or domestic consumption.

Dispositif permettant le traitement du poisson et la production d'azote liquide en mer

La communication présente un dispositif permettant le traitement et la congélation cryogénique de filets de poisson à bord d'un bateau-mère, à bord duquel a également lieu la production du fluide cryogénique (azote liquide). La méthode pourrait convenir particulièrement bien aux pays en voie de développement, car elle envisage l'utilisation des petits bateaux de pêche existants et assure, sans investissements élevés, une grande souplesse de fonctionnement. Le bateau-usine envisagé n'est pas un bâtiment rapide, mais plutôt un atelier de traitement mobile.

Les auteurs traitent de la possibilité d'installer à bord un système fournissant de l'énergie pour tous les besoins du navire, et examinent aussi les aspects économiques de l'usine, dont la capacité de production est de 25 t/j de filets congelés. Ils envisagent d'utiliser du mazout ou du gaz naturel liquéfié pour alimenter une turbine à gaz génératrice, avec récupération des chaleurs perdues.

La communication étudie les dimensions des groupes générateurs et le coût d'exploitation, ainsi que le prix de revient de l'azote liquide. Les filets, d'une grande valeur commerciale, sont surgelés individuellement et conviennent parfaitement à l'exportation. Des sous-produits, comme la farine de poisson ou les concentrés de protéines de poisson, se prêtent également à l'exportation ou à la consommation intérieure.

Sistemas de elaboración de pescado en el mar y de producción de nitrógeno líquido

En este informe se ofrece un plan para la elaboración y congelación criógena de filetes de pescado a bordo de un buque nodriza. El refrigerante, un flúido criógeno (nitrógeno líquido), se produce también a bordo del buque nodriza. Este método sería especialmente adecuado para los países en desarrollo ya que supone el empleo de pequeños barcos pesqueros ya existentes y facilita la flexibilidad de las operaciones sin elevados costos de capital. El propuesto buque pesquero factoría no es una embarcación de gran velocidad sino más bien una fábrica móvil de elaboración de pescado.

En este informe se expone la posibilidad de incorporar en el barco una fábrica completa accionada por energía eléctrica. Se indica también la economía de la fábrica, cuya capacidad es de 25 toneladas diarias de filetes congelados. Se examina el empleo del fueloil o del gas natural licuado en un motor primario de turbina a gas mediante la utilización del calor perdido. Se estudia la fuerza motriz, el gasto de las operaciones y el costo del nitrógeno líquido Los filetes de mayor valor se congelan rápidamente destinándose a las ventas de exportación. Los subproductos de los bloques de filetes congelados, la harina de pescado, o los concentrados proteínicos de pescado son también productos que se destinan a la exportación o al consumo en el país.

DURING the last decade, we have witnessed a series of events which have caused significant changes in the operation of the deep-sea fishing industry.

(1) Relocation of fishing grounds because of either extension of territorial sea limits or overfishing of formerly highly productive areas.

(2) Construction of faster factory ships capable of greater production rates and larger storage capacity.

(3) Improvement in equipment for locating fish electronically or by the use of spotter-type aircraft.

(4) Improvement in the art of catching, handling and processing of fish including the use of automatic equipment for heading, skinning and filleting.

(5) Improvement in refrigeration equipment and types of quick freezers and hold freezers.

All of the aforementioned changes and improvements have contributed to the approximate doubling of the yearly catch of fish from all of the world seas from 30 million t/year to almost 60 million t/year during a 10-year period. Of this total catch, it has been estimated by various sources that only about 9 per cent (approximately 5 million t) of fish were frozen, with the larger portion of that amount being frozen as block. In this paper we hope to show the benefits and feasibility of liquid nitrogen freezing of fillets rather than block. The main benefits are the retention of fresh fish flavour and the higher value of this product.

We have already discussed the advantages of using liquid nitrogen (LN) for freezing of fish products (Breyer, Wagner and Seliber, 1967). It was pointed out that at atmospheric pressure LN has a temperature of −196°C (−320°F), permitting the design of unusually compact freezers. In addition, the inert nature of this refrigerant (R728) makes it possible to spray it directly on the product thus eliminating heat exchangers. The fish production plan which we shall outline is especially suited to fishing communities in the less industrialized nations. Their needs are to produce greater quantities of higher-priced product for export such as popular crustaceans, high quality frozen fillets and fish steaks, as well as fish products for home consumption such as fish block, fish protein concentrate (FPC) and fish meal for animal consumption.

A proper fishing plan must have, as an essential ingredient, "the option to be flexible". Without an economical way of changing fishing grounds or gear or fish processing technique, we are in danger of returning to

a "feast or famine" productivity schedule. Fast freezing with LN on small catcher vessels working in conjunction with large factory ships can contribute to the answer.

FACTORY SHIP PLAN

In a paper entitled "Aspects of factory ship operations", Mogens Jul (1955) very well summarized methods for using factory ships, barges and freeze trawlers. The four methods noted were:

(1) The mobile plant, i.e., plants installed on barges or boats but depending on shore facilities for labour, water, etc. Several salmon cannery scows fall into this group.

(2) The mothership, i.e., a completely self-contained plant aboard a ship, but which is dependent on catcher boats for raw material. Motherships generally also act as supply boats for the catchers. Whale factory ships are in this category.

(3) The factory ship proper, i.e., boats equipped for both fishing and processing, e.g., the *Deep Sea* and the *Fairtry*.

(4) The fishing boat equipped for processing part of the catch, e.g., trawlers with fish meal or freezer installations.

A combination of methods (1) and (2), which may be economically attractive for developing nations, would consist of either a barge or a self-propelled factory ship which, besides its regular functions, would carry the LN generating plant and would operate in conjunction with a fleet of small fishing vessels. The normal operating radius of the factory vessel would not be more than 500 miles. It would anchor in coastal waters and receive its supplies from shore. The factory vessel would use a gas turbine to provide the mechanical energy for nitrogen liquefication. The use of identical gas turbines for main propulsion and nitrogen liquefication permits interchangeability. These power units develop 15,000 kg steam/h (1,000 b.h.p.) and weigh only 592 kg (1,300 lb) each. Exhaust gases would be utilized to generate steam in a waste heat boiler. The steam would be used in an absorption-type refrigeration system and in the fish meal plant. Refrigeration produced by the absorption unit would be used in the fish hold freezer and in cooling the compressed air, thereby increasing the efficiency of the LN plant. In this "total energy" system, electricity for lighting and for power would also be generated (fig 1).

GENERATION OF LIQUID NITROGEN

It is a fairly accurate approximation to say that 1 lb of LN is required to freeze 1 lb of fish. From this figure we can determine the capacity of the LN plant required to meet the expected production goals. A plant which freezes 25 t of fish per day would be required to generate 25 t of LN per day. Large cryogenic storage tanks are needed to store LN. This permits steady operation of the nitrogen liquefier and use of the LN as required.

A 25 t/day LN plant may be mechanically driven directly by a gas turbine power unit capable of burning diesel fuel. The elimination of large electric generators and motors and their switch gear is highly desirable. The overall thermal efficiency of this system is high. A typical flow diagram is shown in fig 1. The cost of operation and cost of LN is shown in table 1. The overall cost of LN is

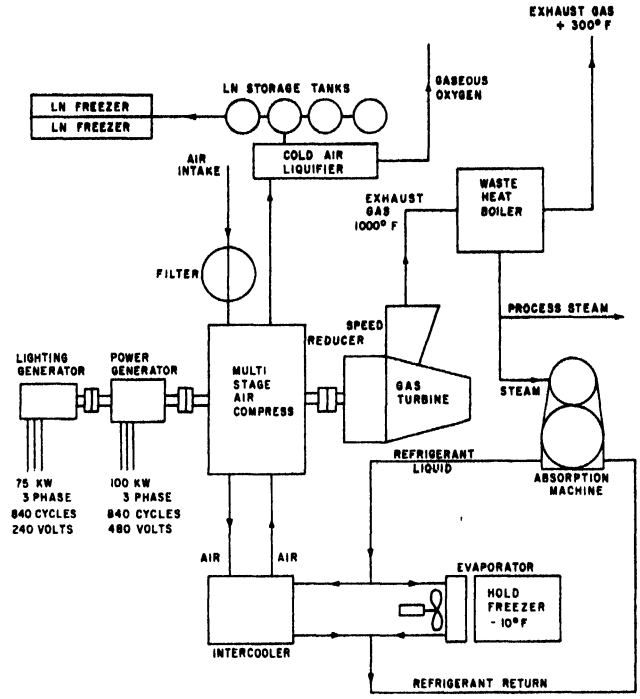


Fig 1. Flow diagram: "Total energy"—liquid nitrogen generation and utilization system

shown to be approximately U.S.$0.034/kg (U.S. $0.0154/lb). By comparison, industrial gas companies sell LN to large users in certain parts of the United States and Great Britain at a price between U.S.$0.03 to $0.04/kg (U.S. $0.015 to $0.02/lb). Assuming a minimum of 200 working days per year, this factory vessel would process 5,000 t of fillets and 2,000 t of fish meal from a live catch of approximately 14,000 t. This is a very substantial catch for a developing nation or even a developed one.

An LN plant of this size can be mounted in a small area. Due to the necessity for maintaining continuous operation of the LN plant, it is necessary to provide as much cryogenic storage capacity as possible. The fishing vessels also store nitrogen in cryogenic containers in their hold, and adequate supplies must be maintained for prompt loading into their tanks.

The possibility of providing liquefied natural gas (LNG) as fuel for the gas turbine, using the refrigeration available in vaporizing the natural gas prior to burning which would reduce the power required to generate LN, is technically tempting. From a practical standpoint, it may be difficult to justify building a shore tank to store the LNG and establish the cryogenic hardware to service the floating fish factory. A detailed study of each installation is necessary to make a proper economic balance.

Of primary importance is the absolute necessity of reliability of this equipment. Fortunately, the gas turbine and the nitrogen plant are automated and are highly reliable. Only a few technicians are required to supervise this part of the operation.

PROCESSING AND FREEZING EQUIPMENT

The success of the entire operation requires the consistent production of the highest quality fillets. Since these high-value products are the goal, every effort must be made to

TABLE 1. COST FACTORS IN LIQUID NITROGEN GENERATION AND UTILIZATION (*see* fig 1)

1. *Power and steam generation*	
U.S. $180,000.00	Installed cost, 1,100 hp gas turbine, waste heat boiler, absorption machine, hold freeze evaporator, lighting and power generation, intercooler. 200 days/year operation (4,800 h)
U.S. $21,600.00	Annual amortization expense (10-year period)
U.S. $4.50	Hourly expense Fuel input—3.15 million kcal/h (12.5 million Btu/h) Fuel oil cost—U.S. $0.0264/l (10 c/gal), 9,300 kcal/l (140,000 Btu/gal)
U.S. $8.90	Hourly fuel cost—(12.5 million) (10 c)/140,000
U.S. $13.40	Hourly cost of power plant ($4.50 + $8.90)
U.S. $0.014	Cost of 1 kg of LN [U.S. $0.0064/lb of LN ($13.40 × 24/50,000)]
2. *Liquid nitrogen generation and storage*	
U.S. $750,000.00	Installed cost of LN generator, 25 t/day, and cryogenic storage tanks
U.S. $90,000.00	Annual amortization expense
4,540 t (10 million lb)	Annual production [22.7 t/day × 200 days (50,000 lb/day × 200 days)]
U.S. $0.02/kg (U.S. $0.009/lb)	Nitrogen unit cost per kg (lb) [U.S. $90,000/4,540 t ($90,000/10 million lb)]
3. *Liquid nitrogen cost*	Power cost and unit cost 0.014 + 0.02 = U.S. $0.034/kg (U.S. $0.0154/lb)
Note: Operating plant for 330 days per year reduces LN cost to U.S. $0.024/kg (U.S. $0.011/lb)	
4. *LN freezer cost*	
U.S. $100,000.00	Two machines rated at 900 kg/h (2,000 lb/h), continuous duty
U.S. $12,000.00	Annual amortization expense
U.S. $2.64/t (U.S. $0.0012/lb)	Cost per t (lb) of fish [U.S. $12,000/4,540 t (U.S. $12,000/10 million lb)]
5. *Fish freezing costs*	1 t (lb) of LN freezes 1 t (lb) of fish
U.S. $34/t (U.S. $0.0154/lb)	Cost of nitrogen
U.S. $2.64/t (U.S. $0.0012/lb)	Cost of freezer
U.S. $36.64/t (U.S. $0.0166/lb)	Total

Notes:
(1) Refrigeration and all steam-operating expense (fuel) charged against LN generation.
(2) Additional cost for factory vessel, filleting equipment, hold freezer, storage, labour, etc., to be added.
(3) Amortization of all components in 10 years at 4 per cent interest. The 4 per cent interest rate on unpaid balance chosen to illustrate "Developing Nation" cost.
(4) Turbine life claimed to be 100,000 h so that life expectation under these conditions is 20 years.

avoid losses in quality or quantity of these fillets. The design of the fish plant depends, to a considerable degree, upon the type of catch expected. Heading, filleting and skinning equipment should be considered where large quantities of the same size and species will be handled. To preserve quality, expeditious off-loading of the fishing vessels on to the floating factory and quick processing and freezing is necessary. A peak freezing rate of at least double the average rate of production is desirable.

In the case of the LN freezers, two standard machines, each rated at 900 kg/h (2,000 lb/h), would meet this requirement. Fig 2 shows such a freezer. These machines are each approximately 10.4 m (34 ft) long including input and output conveyors and can be mounted side by side in a width of 2.75 m (9 ft). These freezers are belt-type units and lend themselves well to continuous operation.

As shown in table 1, the cost of freezing fish is U.S. $0.0365/kg (U.S. $0.0166/lb), although this does not include filleting equipment, labour and many other processing costs. A minimum of labour is required to load and unload fillets into this freezer. These machines can also handle 7.5-cm (3-in) thick blocks of filleted fish and fish steaks. A number of shore-based LN fillet freezing installations are in operation. In addition, a fish meal plant would process offal and trash fish.

CONCLUSION

A specially designed fish factory vessel or a well-engineered conversion of an existing vessel is necessary for the optimization of fillet production and LN generation. All of the major components required for the successful functioning of this plan are standard production items. Some of the other components for the catcher vessels, such as the small cryogenic containers and freezers, are not production items, but are well within our technology.

The above plan has the advantages of dealing in a constructive way with many fishery problems; utilization of existing manpower and fishing gear; the landing of products designed to meet the needs of home consumption and foreign trade; and profitability in proper proportion to investment. Liquid nitrogen may well provide the fisheries of the world with a practical new tool to increase productivity.

References

BREYER, F, WAGNER, R C and SELIBER, J 1967 A system for liquid nitrogen freezing of fishery products. XIIth International Congress of Refrigeration, 8th August–6th September, Madrid.

Aspects of factory ship operations, by Jul, M In *Fishing Boats of the World*, ed. J-O. Traung, Fishing News (Books) Ltd., London, p. 551. 1955

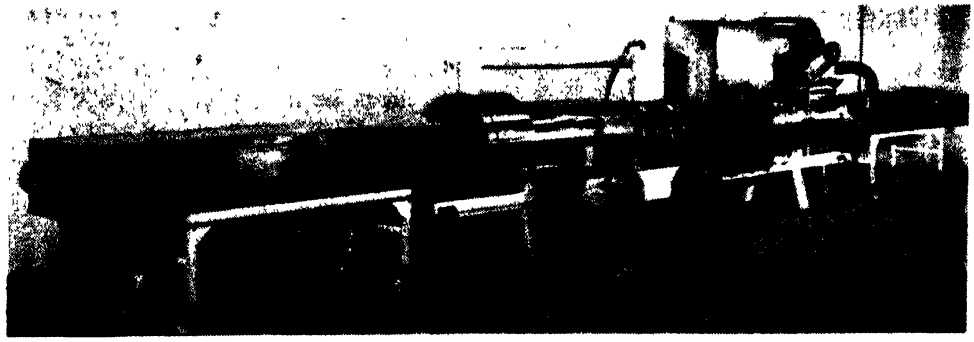


Fig 2. Liquid nitrogen flash freeze process

Freezing Rates of Seafoods as Influenced by Heat Transfer Coefficients of Liquid Refrigerants

by D. W. Baker and S. E. Charm

Freezing rates of seafoods as influenced by heat transfer coefficients of liquid refrigerants

The heat transfer coefficients of liquid nitrogen, Freon 12 and propylene glycol, were evaluated by measuring the temperature change at the centre of an immersed block of ice. The results indicated that the heat transfer coefficients were as follows:

Cooling medium	*Heat transfer coefficient (cal/sec cm² °C)*
Freon 12 (−5.7°C)	79.5×10^{-4}
Freon 12 and 114 (−17.8°C)	39.2×10^{-4}
Freon 12 and 114 (−12.2°C)	23.2×10^{-4}
Liquid nitrogen (−196°C)	30.5×10^{-4}
Propylene glycol (−5.7°C)	3.12×10^{-4}
Propylene glycol (−17.8°C)	2.60×10^{-4}
Propylene glycol (−12.2°C)	2.44×10^{-4}

It was found that the Nagaoka, Takaji and Hotani (1955) variation of Plank's equation did not accurately predict freezing times of controlled packages of fish.

Taux de congélation des produits marins en fonction de coefficient de transmission de chaleur des réfrigérants liquides

Les coefficients de transmission de chaleur de l'azote liquide, du Fréon 12 et du propylène glycol ont été évalués en mesurant les modifications de température au centre d'un bloc de glace immergé. On a obtenu les valeurs suivantes:

Agent frigorigène	*Coefficient de transmission de chaleur (cal/sec cm² °C)*
Fréon 12 (−5,7°C)	$79,5 \times 10^{-4}$
Fréon 12 et 114 (−17,8°C)	$39,2 \times 10^{-4}$
Fréon 12 et 114 (−12,2°C)	$23,2 \times 10^{-4}$
Azote liquide (−196°C)	$30,5 \times 10^{-4}$
Propylène glycol (−5,7°C)	$3,12 \times 10^{-4}$
Propylène glycol (−17,8°C)	$2,60 \times 10^{-4}$
Propylène glycol (−12,2°C)	$2,44 \times 10^{-4}$

On a constaté que la variante de l'équation de Plank proposée par Nagaoka, Takiji and Hohani (1955), ne permettait pas de prévoir avec précision les temps de congélation des paquets de poissons examinés.

Efectos de los coeficientes de transmisión térmica de los refrigerantes líquidos en las velocidades de congelación de los alimentos de origen marino

Se evaluaron los coeficientes de transmisión térmica del nitrógeno líquido, Freón 12 y propilenglicol, midiendo el cambio de temperatura en el centro de un bloque de hielo sumergido. Los resultados indicaron que los coeficientes de transmisión térmica fueron los siguientes:

Medio refrigerante	*Coeficiente de transmisión térmica (cal/seg cm² °C)*
Freón 12 (−5,7°C)	$79,5 \times 10^{-4}$
Freón 12 y 114 (−17,8°C)	$39,2 \times 10^{-4}$
Freón 12 y 114 (−12,2°C)	$23,2 \times 10^{-4}$
Nitrógeno líquido (−196°C)	$30,5 \times 10^{-4}$
Propilenglicol (−5,7°C)	$3,12 \times 10^{-4}$
Propilenglicol (−17,8°C)	$2,60 \times 10^{-4}$
Propilenglicol (−12,2°C)	$2,44 \times 10^{-4}$

Se halló que la variación Nagaoka, Takiji y Hohani (1955) de la ecuación de Plank no pronosticaba con precisión los tiempos de congelación de los envases controlados del pescado.

IMMERSION freezing as a means of rapidly freezing food materials has been studied for some time. The commonly employed media for this purpose are liquid nitrogen and propylene glycol. Another medium is freon, the use of which has recently been suggested. In the work reported here, the heat-transfer coefficients of these media and their freezing characteristics are compared when they are applied to the immersion freezing of fish, and calculations are made of the freezing times when these media are used.

PROCEDURE

Preparing the test sample

A fresh fish fillet (either haddock or cod) was placed in a frame, which formed the fillet into a uniform shape. A copper-constantan thermocouple probe, designed to measure the distribution of temperature throughout the thickness of the framed sample, was inserted in the fillet. The frame and fillet were then placed in a 0.0254-mm thick Cryovac bag which was evacuated so that no air pockets remained in the bag; and the bag and its contents were placed in the freezing medium.

The frame

The frame was so constructed that the transfer of heat through the lateral faces of the fillet was negligible compared with the transfer of heat through the parallel faces.

The dimensions of the frame were 7.6 × 7.6 × 2.2 cm. It was constructed of plywood, and the lateral faces were insulated with urethane foam 2.5 cm thick. It was estimated that less than 2 per cent of the heat transferred would pass through the lateral faces under these conditions.

Thermocouple probe

Six copper-constantan thermocouple elements were imbedded in a lucite rod 3.2 mm apart along the length of the probe. They were calibrated with a precision potentiometer to the nearest 0.06°C (0.1°F).

The probe permitted the determination of the centre-line temperature in the framed fillet by a plot of the temperature as a function of the distance along the thickness and observation of the point of greatest temperature lag.

Freezing media

The freezing media employed were Freon 12 [−30.1°C (−21.7°F)], Freon 114 [+3.6°C (+38.4°F)], liquid nitrogen [−197.3°C (−320.4°F)], and propylene glycol cooled by external means.

By the use of mixtures of Freon 12 and 114, it was possible to obtain boiling temperatures varying from −30.1°C to +3.6°C (−21.7°F to +38.4°F).

The freezing temperatures studied with the freons and propylene glycol were −30.1°C (−21.7°F), −23.3°C (−10°F), −17.8°C (0°F) and −12.2°C (+10°F).

Determination of heat-transfer coefficient

In the determination of the heat-transfer coefficients under each of the freezing conditions, a block of ice containing a thermocouple probe and in the insulated frame, all in a plastic bag, was first allowed to come to equilibrium at a temperature of 0°C (32°F). The framed ice block was then placed in the freezing medium to be tested which, of course, was at a temperature different from that of the ice. The centreline ice temperature was determined as a function of time and, from this determination, the heat-transfer coefficient was calculated as shown in the calculations section.

Whitening and cracking

One of the effects of rapid freezing is whitening of the product and, in some cases, cracking or shattering. The effect of freezing rate and temperature on whitening and cracking was also studied.

CALCULATIONS

Heat-transfer coefficient

The heat-transfer coefficient in the various freezing media was evaluated by use of the ice time-temperature curve and the method suggested by Charm (1963).

An example of the calculations is shown in the following:

The centreline time-temperature data for the framed ice block, which was initially at 0°C (32°F) and was immersed in freon at −30.1°C (−21.7°F) is plotted as

$$\log \frac{T_m - T}{T_m - T_o} \text{ vs. time in min}$$

where T_m is the temperature of the medium, T the ice temperature at time of measurement and T_o the initial ice temperature.

The time required for the straight line portion of the curve to pass through one log cycle is known as f. In this case f is 4.1 min (fig 2).

The value of f obtained from the data is used to evaluate λ_1^2 in the following equation

$$\frac{2.303}{af} = \lambda_1^2 \qquad (1)$$

where a is the thermal diffusivity of ice over the temperature range for which f was evaluated and λ_1 is a function of h.

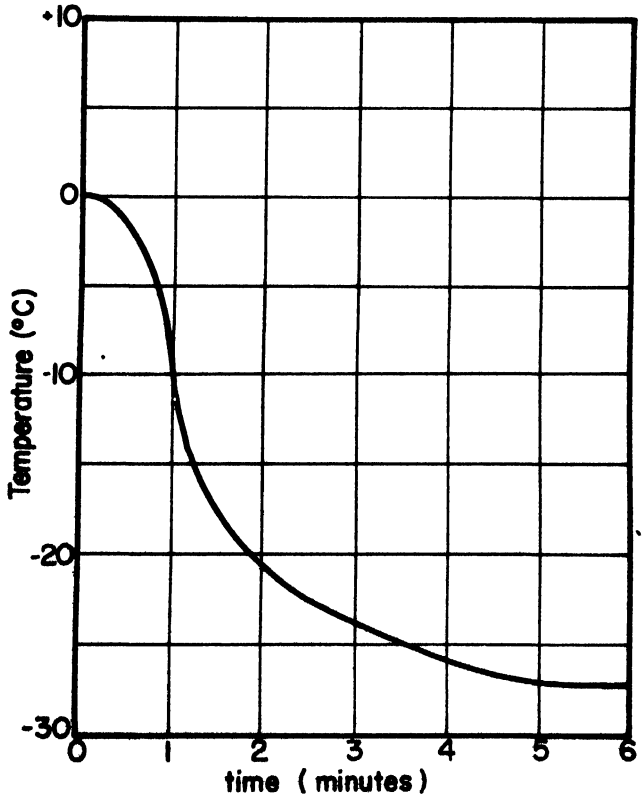


Fig 1. Cooling curve for vertical ice-block in Freon 12 at −30.1°C

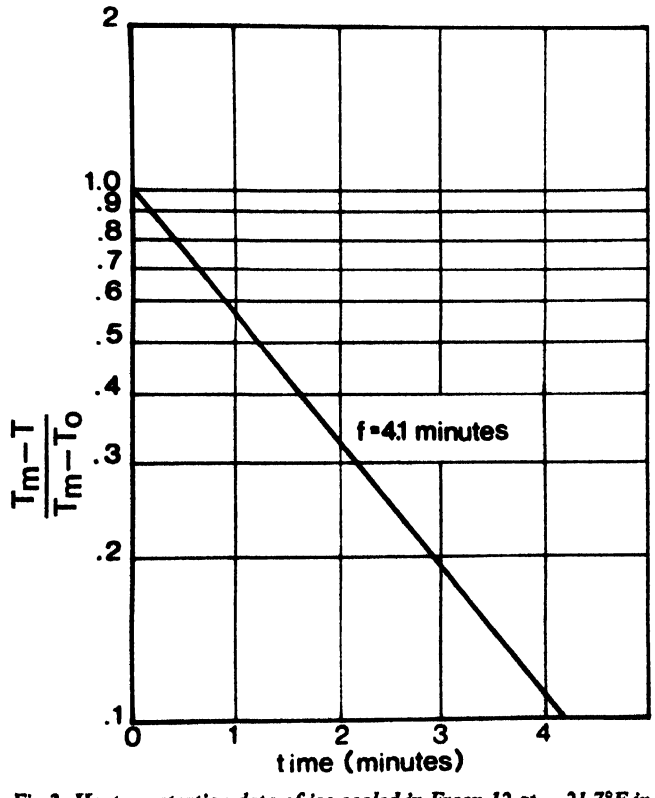


Fig 2. Heat penetration data of ice cooled in Freon 12 at −21.7°F in the vertical plane plotted on semi-log paper

The heat transfer coefficient h may then be found by trial and error as follows:

(1) Assume a value for h.

(2) Evaluate $m = hb/k$, where b = half thickness of slab and k = thermal conductivity of ice.

(3) Find B_1 corresponding to m from fig 3 or table 1.

(4) Solve for $B_1/b = \lambda_1$.

(5) Calculate λ_1^2 from this relationship and compare with the value obtained from equation (1).

(6) Repeat using different assumed values of h until the value is found which corresponds to the value of λ_1^2 obtained from equation (1); this may be done fairly readily by plotting assumed values of h against calculated values of λ_1^2 (fig 4).

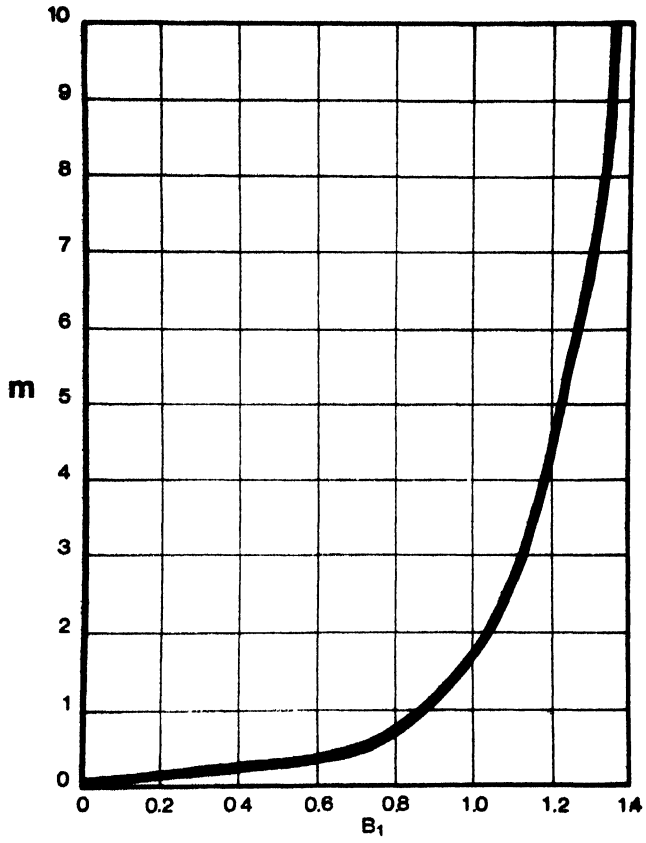


Fig 3. m vs B_1

TABLE 1. NUMBERS FOR A PLOT OF m VERSUS B_1

m	B_1	m	B_1
0	0	1.5	0.9882
0.001	0.0316	2.0	1.0769
0.002	0.0447	3.0	1.1925
0.004	0.0632	4.0	1.2646
0.006	0.0774	5.0	1.3138
0.008	0.0893	6.0	1.3496
0.01	0.0998	7.0	1.3766
0.02	0.1410	8.0	1.3978
0.04	0.1987	9.0	1.4149
0.06	0.2425	10.0	1.4289
0.08	0.2791		
0.1	0.3111		
0.2	0.4328		
0.3	0.5218		
0.4	0.5932		
0.5	0.6533		
0.6	0.7051		
0.7	0.7506		
0.8	0.7910		
0.9	0.8274		
1.0	0.8603		

If, in the example at hand, a value of 54.2×10^{-4} cal/sec cm^2 °C (40 Btu/h. ft^2. °F) is assumed for h, hb/k is found to be 1.16 and from fig 3 B_1 is 0.91, whence

$$\frac{B_1}{b} = \lambda_1$$

is 25.5 and λ_1^2 is 650, but

$$\frac{2.303}{af} = \lambda_1^2 = 691$$

After calculating λ_1^2 from several other assumed values of h, the correct value of h was found to be 62.3×10^{-4} cal/s.cm^2 °C (46 Btu/h. ft^2. °F).

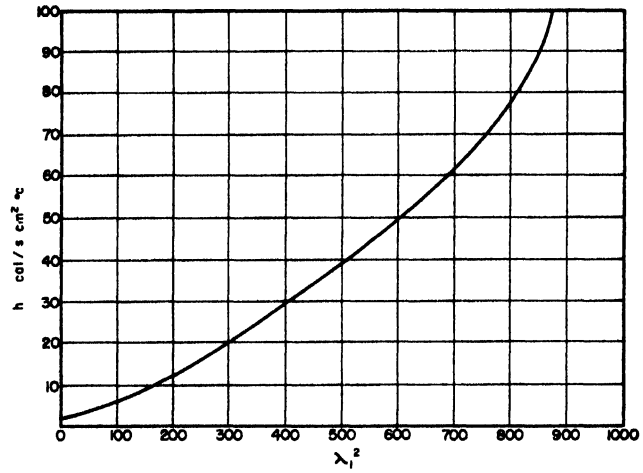


Fig 4. Heat transfer coefficient h vs λ_1^2

Calculating freezing time

Nagaoka, Takaji and Hotani (1955) have provided the following modified version of Plank's basic formula, which involves the initial temperature and final temperature:

$$Z = C_w(T_1 - T_2) + L_f + C_f(T_2 - T_3)$$

where Z = heat to be removed from fish
C_w = specific heat above freezing temperature = 0.84 cal/g°C
T_1 = initial temperature of fish
T_2 = temperature at which fish freezes
L_f = latent heat of fusion = 64 cal/g
C_f = specific heat below freezing temperature = 0.44 cal/g°C
T_3 = final temperature of frozen product

then

$$\theta = [1 + 0.0044(T_1 - T_2)]\left[\frac{Z}{V(T_2 - T_4)}\left(P\frac{d}{h} + \frac{Rd^2}{K}\right)\right]$$

where θ = freezing time
V = specific volume of ice = 1.1 cm^3/g
T_4 = temperature of medium
P = half for slab
d = thickness of slab = 2.23 cm
h = coefficient of heat transfer
R = one-eighth for slab
K = thermal conductivity of frozen material = 0.004 cal/s.cm^2. °C/cm (0.9 Btu/h. ft^2. °F/ft)

RESULTS

Fig 1 shows a typical cooling curve for ice and the heat penetration data used in determining the heat-transfer coefficient; fig 5 shows the corresponding temperature-time curve of a fish sample.

Fig 6 shows the boiling-point temperature obtained by varying the percentage composition of a Freon 12 and 114 mixture.

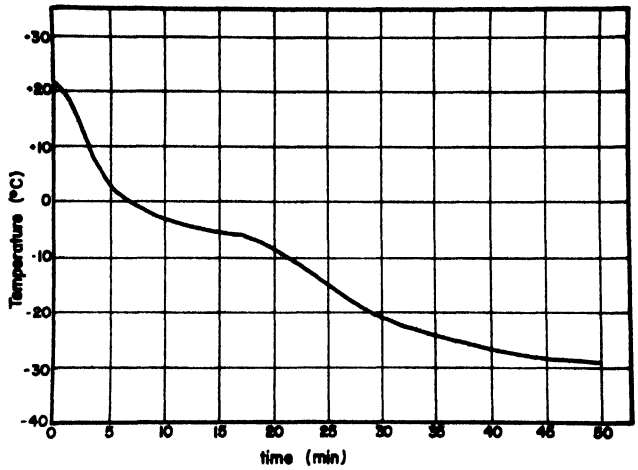


Fig 5. Cooling curve or vertical haddock block in Freon 12 at −30.1°C

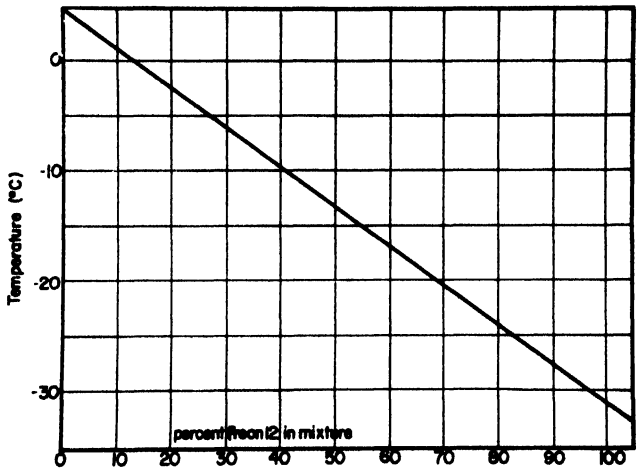


Fig 6. Boiling point of mixtures of Freon 12 and Freon 14

Table 2 shows the times required to reach various stages of freezing relative to the freezing medium, its temperature versus initial product temperature, and total freezing time.

Table 3 shows the calculated heat-transfer coefficients of the various freezing media as determined from the heat-penetration data of ice both in the horizontal and vertical plane in freon and liquid nitrogen, and in the vertical plane in propylene glycol.

Whitening

A whitening effect took place in all the frozen samples with the exception of the packaged sample in freon at −6.7°C (+20°F) and both samples in propylene glycol at −6.7°C (+20°F). It is not generally known exactly why whitening of the frozen product occurs; however, in theory, there are several possible reasons. One possibility is that the formation of ice crystals of a particular size and structure reflect light in such a manner as to give the chalky-white appearance. A change in this crystalline formation or rehydration of the desiccated surface by post-freezing glazing restores the natural colour of the product. In substantiation of the theory, post-freezing glazing does provide an additional layer of ice crystals of still different size and structure, which reflect light in a manner that gives the appearance of the natural colour.

Several observations have been made concerning whitening; they are:

(1) whitening disappears when the product is thawed;
(2) frozen samples that are cut open or broken apart have the same whitening effect throughout the thickness of the samples;
(3) the whitening effect is not due to protein denaturation, since it is not permanent.

TABLE 2. EXPERIMENTAL FREEZING TIMES

Freezing media	*Freezing media temperature* (°C)	*Initial temperature of fish* (°C)	*Time through freezing zone* (min)	*Time to final temperature* (min)	*Total freezing time* (min)
Freon 12	−30.1	15.6	15	26.5	49
Freon 12 and 114	−23.3	13.3	20	33	63
Freon 12 and 114	−17.8	13.9	20	34	69
Freon 12 and 114	−12.2	22.8	65	65	150
Liquid nitrogen	−197.3	21.7	0.67	2.2	3.67
Propylene glycol	−30.1	17.8	40	136	196

TABLE 3. HEAT TRANSFER COEFFICIENTS OF DIFFERENT MEDIA AT DIFFERENT TEMPERATURES

Freezing media	*Media temperature* (°C)	*Sample position*	*f*	*h*
Freon 12	−30.1	Vertical	4.1	62.3×10^{-4}
Freon 12	−30.1	Horizontal	4.7	54.2×10^{-4}
Freon 12 and 114	−17.8	Vertical	5.67	43.0×10^{-4}
Freon 12 and 114	−17.8	Horizontal	6.5	35.9×10^{-4}
Freon 12 and 114	−12.2	Vertical	11.6	17.8×10^{-4}
Freon 12 and 114	−12.2	Horizontal	12.6	16.1×10^{-4}
Liquid nitrogen	−197.3	Vertical	8.8	25.5×10^{-4}
Liquid nitrogen	−197.3	Horizontal	10.0	21.0×10^{-4}
Propylene glycol	−30.1	Vertical	66.0	3.1×10^{-4}
Propylene glycol	−17.8	Vertical	119.0	2.6×10^{-4}
Propylene glycol	−12.2	Vertical	141.0	2.4×10^{-4}

DISCUSSION OF RESULTS

From table 3, the heat-transfer coefficient for Freon 12 at −30.1°C (−21.7°F) is seen to be about 20 times that of propylene glycol and more than two times that of liquid nitrogen at −197.3°C (−320.4°F). In fact, it is necessary to make mixtures of Freon 12 and 114 at −12.2°C (+10°F) before the heat-transfer coefficient is comparable with that of liquid nitrogen, and this coefficient is still approximately six times higher than that of propylene glycol.

TABLE 4. EXPERIMENTAL VERSUS CALCULATED TIME FOR FISH SAMPLES TO REACH PRE-DETERMINED TEMPERATURE UNDER VARIOUS FREEZING CONDITIONS

(Nagaoka formula)

Freezing media	*Freezing media temperature* (°C)	*Initial temperature of fish* (°C)	*Position of fish sample*	*Calculated heat transfer coefficient* (*cal/sec cm² °C*)	*Time to reach pre-determined temperature*	
					Experimental (*h*)	*Calculated* (*h*)
Freon 12	−30.1	23.3	Vertical	$62.3 \times 10^{-}$	0.458	0.39
Freon 12	−30.1	15.6	Horizontal	$54.2 \times 10^{-}$	0.467	0.37
Freon 12 and 114	−17.8	—	Vertical	$43.0 \times 10^{-}$	—	—
Freon 12 and 114	−17.8	13.9	Horizontal	$35.9 \times 10^{-}$	0.850	0.80
Freon 12 and 114	−12.2	—	Vertical	$17.8 \times 10^{-}$	—	—
Freon 12 and 114	−12.2	22.8	Horizontal	$16.1 \times 10^{-}$	1.583	2.27
Liquid nitrogen	−197.3	21.7	Vertical	$25.5 \times 10^{-}$	0.043	0.088
Liquid nitrogen	−197.3	16.7	Horizontal	$21.0 \times 10^{-}$	0.087	0.134
Propylene glycol	−30.1	17.8	Vertical	$3.1 \times 10^{-}$	1.883	3.417
Propylene glycol	−17.8	—	Vertical	$2.6 \times 10^{-}$		
Propylene glycol	−12.2	—	Vertical	$2.4 \times 10^{-}$		

TABLE 5. WHITENING

Media	*Temperature* (°C)	*Rate of whitening*
Freon 12	−30.1	Immediately
Freon 12 and 114	−23.3	Quite fully developed in 5 s
Freon 12 and 114	−17.8	Quite fully developed in 10 s
Freon 12 and 114	−12.2	Quite fully developed in 30 s
Freon 12 and 114	−6.67	After 30 min, there was only slight whitening of corners and high spots of unprotected sample. Sample in Cryovac bag showed no whitening. Both samples were solidly frozen
Liquid nitrogen	−197.3	Immediately; also cracking
Propylene glycol	−30.1	Started developing on edges in 15 s; totally white in 3 min
Propylene glycol	−17.8	Started developing in 3 min; fully developed in 6 min
Propylene glycol	−12.2	Started developing in 6 min; fairly noticeable in 10 min
Propylene glycol	−6.67	After 3 h, sample in Cryovac bag was frozen solid and showed no whitening. Exposed sample also showed no whitening but had absorbed so much glycol that only the centre was hard. Surface was saturated with glycol and soft

Samples immersed in propylene glycol at −12.2°C for 5 min and then frozen in freon at −30.1°C turned white in the freon.

Immersion freezing vertically in both freon and liquid nitrogen present slightly higher heat-transfer coefficients than immersion freezing horizontally. This difference is probably due to the blanket of trapped vapour on the bottom side of the horizontally frozen sample.

Use of these calculated heat-transfer coefficients did not permit a calculation of freezing times by the use of the Nagaoka modification of Plank's formula (table 4).

When Nagaoka's modification of Plank's formula was used to evaluate heat-transfer coefficients from experimental freezing times and estimated thermal properties of fish, a range of heat-transfer coefficients was found. When averaged out, this calculated value of heat-transfer coefficient was found to be about the same as the heat-transfer coefficient determined from the ice time-temperature curve.

Although whitening is not generally thought to be detrimental, it is objectionable from the aspect of appearance. The whitening can be removed from the surface by further treatment, such as by the application of a post-freezing glaze, which, in many instances, is applied. It is desirable to be able to immersion-freeze without whitening and thus to eliminate the necessity for further treatment; however, further investigation of this problem is necessary.

The one advantage in using liquid nitrogen lies in its large initial temperature difference, which tends to make up for its lack of efficiency and lower heat-transfer coefficient. It, however, frequently has the disadvantage of cracking or even shattering the product being frozen.

Propylene glycol has the disadvantage of being extremely messy to handle; and in comparison with either freon or liquid nitrogen, it has very poor heat-transfer characteristics.

References

CHARM, S E 1963 *Fundamentals of Food Engineering*, The AVI Publishing Co., Inc., Westport, Conn.

NAGAOKA, J., TAKAJI, S and HOTANI, S 1955 Experiments on the freezing of fish in an air blast freezer. *Proc. IX Int. Congr. Refrig.*, Paris, Paper 4, p. 321.

DISCUSSION

Holston (U.S.A.): I agree with Dalcq that $CaCl_2$ would make a more efficient and practical immersion freezing system than does NaCl. I agree also that salt penetration is at a much lower rate since the outer circumference of the fish is frozen so much faster. However, when tested under commercial conditions aboard the trawler *Delaware*, followed by six months bulk storage at −15°C (5°F) in a commercial storage warehouse, unwashed fish frozen in $CaCl_2$ brines were found to exhibit off-flavours and a very poor appearance. $CaCl_2$ and glucose brines seemed to eliminate these problems.

Vyncke (Belgium): In recent years, Norway lobsters (*Nephrops norvegicus* L.) have become of great importance to the fishing industry in several European countries. In Belgium, landings increased from 200 t in 1951 to 705 t in 1966. As about 50 per cent is caught in Icelandic waters, the duration of the voyage (up to 18 days) often affects the quality of the raw crustaceans kept in ice. The increasing popularity and the claimed advantages of liquid-nitrogen freezing in the United States suggested the possible use of this technique for freezing Norway lobsters directly at sea, especially when considering the high value of the product. A series of experiments was started at our research station, the first results of which are given in this report. They deal with a comparison between cryogenic freezing and classical air-blast freezing, for both raw and cooked crustaceans.

The liquid-nitrogen freezer used for these experiments was a Linde Biological Freezer model BF3-2 (Union Carbide Corp., New York). Freezing rate controls were set at 50 (rate adjustment) and 0.3 mA (range calibration) in order to obtain a freezing cycle of about 10 min with a final core temperature of −30°C (−22°F). This freezing time is based on results obtained in the United States with fish fillets and shrimps. The air-blast freezer was a pilot-scale model kept at a constant temperature of −40°C (−40°F); air velocity was 5 m/s.

Medium-sized lobsters (5 kg) were used for each experiment. They were cooked in 20 litres of 8 per cent brine for 8 min, as reported in a previous publication. All experiments were repeated five times.

The freezing curves obtained with the two systems are given in fig 7. Temperatures were measured in the middle of the batches by a copper-constantan thermocouple inserted into a lobster. Average freezing times were respectively 9 and 75 min in liquid-nitrogen and air-blast freezer.

Freezing losses amounted to 0.5 per cent for the former and 2 per cent for the latter system. General appearance on the other hand was the same. The lobsters were carefully glazed twice and kept at −30°C (−22°F) for two weeks; they were then thawed in a chilled room maintained at 5°C (4°F).

A pronounced blackening of the crustaceans was observed upon thawing in air. In 1954 Bailey and Fieger, and Faulkner and others, showed that the action of the enzyme tyrosinase contained in the blood is responsible for this quality degradation. It oxidizes free tyrosine with formation of melanine. The diffusion of tyrosinase through the muscle must have been facilitated by the freezing process. This procedure can thus not be used satisfactorily.

When the frozen lobsters were cooked immediately, no blackening occurred.

Cooking losses were respectively 20 per cent and 23 per cent for liquid-nitrogen and air-blast freezing. Unfrozen control samples averaged 20 per cent. This would indicate that cellular structure of the crustaceans was less damaged by liquid-nitrogen freezing. No marked difference in appearance, texture and flavour, however, could be noticed between the two lots. Moreover, the general conclusion was that the frozen lobsters cooked after a 14-day frozen storage period practically equalled "fresh" samples. If the storage period of the lobster in raw condition is increased, however, it is possible that organoleptic differences may occur. This point needs further investigation.

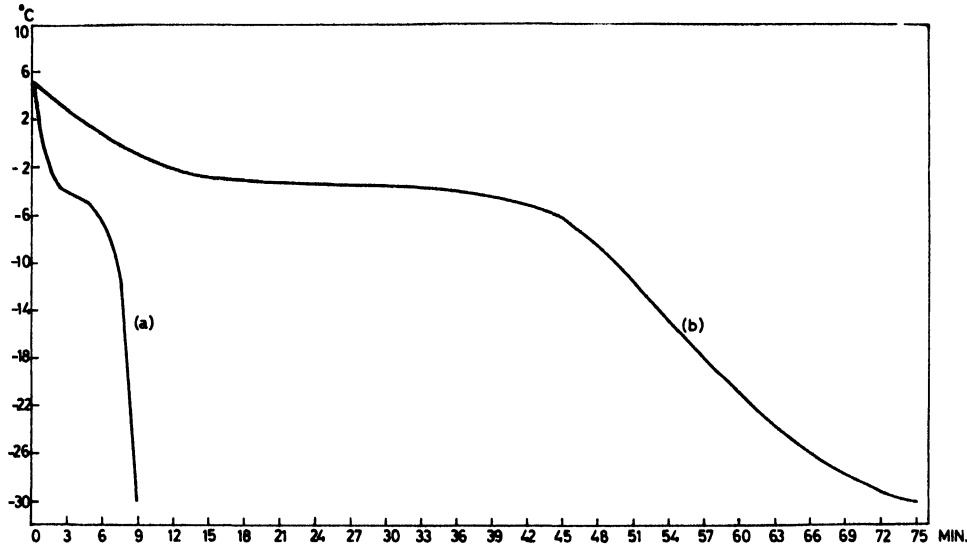


Fig 7. Freezing curves of raw Norwegian lobsters (Nephrops norwegicus L)
(a) *liquid nitrogen freezer;* (b) *air-blast freezer*

The experiments were repeated with previously cooked lobsters. Freezing curves appeared to be very similar to those of raw crustaceans and are not reported here.

After freezing, lobsters were also glazed twice and stored at −30°C (−22°F) for two weeks. They were then thawed in air at 5°C (4°F). The weight of the lobsters frozen with liquid nitrogen remained practically unchanged while the air-blast samples lost 2.7 per cent upon thawing.

Here again, however, no marked difference in appearance, texture and flavour could be detected. Both lots were of excellent quality.

From these results, it can be concluded that the main advantages of the liquid-nitrogen freezing of Norway lobsters are the extremely short freezing times and the reduced loss of weight. There is further strong evidence that freezing time may still be shortened with more appropriate industrial equipment, e.g. freezers with continuous conveyor belt and direct liquid-nitrogen spraying nozzles. The different cryogenic systems were recently reviewed by Holdsworth in 1967.

With regard to the freezing of Norway lobsters directly on board the trawlers, the liquid-nitrogen system seems to have real possibilities. For freezing cooked crustaceans in shore-plants, it seems very promising too. However, the economic aspects (cost of equipment, consumption of liquid nitrogen,

etc.) both on the vessel and in the shore-plant should also be considered carefully. Further work is in progress.

Kreuzer (FAO): We planned to have a paper on individual quick freezing (IQF) of fillets at sea on the program. Unfortunately this did not materialize. I know from the literature that in some countries IQF freezing of fish, freezing single fillets, is making good progress and is a good item to market. In 1957 during a consumer survey in the area of Cologne, Federal Republic of Germany, we saw individual frozen fillets in one shop and asked the proprietor how he was satisfied with the product. He replied that he could sell as much of it as he could get because the housewife likes to select individual fillets of various sizes in accordance with her family's needs. I would like to ask if anyone here has had experience with IQF fillets, either from the technical or from the marketing point of view.

Slavin (U.S.A.): I think the point to be made concerning IQF fillets is that the technology has been pretty well developed. They can be frozen in liquid nitrogen, using a spray to avoid a whitening effect or they can be frozen by an air blast. I think their appeal is in the manner in which they can be marketed to institutional outlets. Institutions like them because they can be used individually without thawing out a whole block of fillets. So it is my view that manufacture of this product will probably increase in the United States.

Seliber (U.S.A.): Supplementing Slavin's remark—the price of IQF fillets, nitrogen frozen, is 54 cents/lb, boxed as haddock tails—the same fish frozen in fillet blocks is sold at 37 cents/lb. The experience of certain fish processors in nitrogen freezing on shore indicates that the economics are highly feasible today. Perhaps it bears emphasis the hardware is available today for economical freezing of high quality fishery products at sea. I believe that for any particular fishery product there should be a very close analysis of any fishery installation including one using liquid nitrogen.

Slavin (U.S.A.): With reference to Baker and Charm's paper, I do not think there is any doubt that the Plank and Nagaoka formula can be improved because our sophistication has improved since these equations were developed some time ago. Perhaps we could encourage some physicists and engineers to become more involved in this field.

Superchilling Fish — A Review

by C. J. Carlson

Superchilling fish—a review

A review was made of the available information concerned with the superchill refrigeration process for fish. Included in the review was a process reported in 1935, the Bellefon–Falliot process, for storing fish in airtight containers at −2° to −3°C (28.4° to 26.6°F). The remainder of the review is concerned with summarization of the patented Portuguese superchilled storage process and the investigations that have been conducted on superchilling in England, Germany, Canada and the United States. In summary, the review points out that partial freezing of the fish flesh, at the lower superchill temperatures, −3° to −2°C (26.6° to 28.4°F), is a major problem because of its subsequent effects on flesh quality as storage progresses.

La sur-refrigération du poisson—examen critique

Les informations disponibles concernant la réfrigération du poisson par la méthode de la sur-réfrigération ont été étudiées. Après avoir rappelé le procédé Bellefon–Falliot, divulgué en 1935, pour l'entreposage du poisson en récipients hermétiques entre −2° et −3°C (28.4° et 26.6°F), l'auteur décrit dans ses grandes lignes le procédé breveté portugais d'entreposage sur-réfrigéré ainsi que les recherches effectuées sur la sur-réfrigération en Angleterre, en Allemagne, au Canada et aux Etats-Unis. L'étude montre que la congélation partielle de la chair de poisson dans la gamme inférieure des températures de sur-réfrigération, soit entre −3° et −2°C (26.6° et 28.4°F), pose un problème important du fait de son incidence sur la qualité de la chair après entreposage prolongé.

Sobreenfriamiento del pescado—un resumen

El trabajo revisiona las informaciones disponibles relacionadas con el proceso de sobreenfriamiento del pescado, incluyendo el proceso Bellefon–Falliot, divulgado en 1935, de almacenamiento del pescado en cajas herméticas a temperaturas de −2° a −3°C (28.4° a 26.6°F).

A continuación, se discuten el proceso patentado de almacenamiento sobreenfriado portugués y las investigaciones correspondientes hechas en la misma materia en el Reino Unido, Alemania, Canada y en los Estados Unidos.

En conclusión el autor señala que la congelación parcial de la carne del pescado que ocurre a las temperaturas más bajas del sobreenfriamiento, o sea, −3° a −2°C (26.6° a 28.4°F) es un problema muy importante dado a los efectos subsequentes en la calidad de la carne del pescado durante el proceso de almacenamiento.

MANY people have their own names for superchilling, as a refrigeration procedure, such as supercooling, light freezing, partial freezing, and some disdainfully call it very poor freezing. For purposes of this review paper, the process will be called superchilling and will be considered as the refrigeration of fish in which the flesh temperatures range from −1° to −3°C (30.2° to 26°6°F).

EARLY WORK ON SUPERCHILLING

An early reference concerning industry interest on the commercial use of superchill temperatures for fish storage appeared in the March issue of the trade journal *Fishing Gazette* (1935). According to the Gazette article, the information printed was a translation of an original paper which had appeared in *La pêche maritime*, Paris, France (no other publication information was given concerning the original paper). The article gave a description of a refrigeration procedure called the Bellefon–Falliot process. In this process, 110 lb of whole fish were packed in individual galvanized iron boxes which could be hermetically sealed by means of a rubber gasket and metal clasps. A continuous stream of brine, maintained at −2° to −3°C (28.4° to 26.6°F), was pumped over the closed boxes, which could be stacked on shelves in a vessel's hold or at a shoreside installation.

It was claimed, in the article, that the quality of the fish was the same after 30 to 40 days of storage, as when the fish were first caught. The reasons given for the high product quality were: exclusion of air in the sealed boxes, maintenance of a regular refrigerated temperature at −2° to −3°C (28.4° to 26.6°F), no sweating, no evaporation, no damage from excessive fish handling, no bruising from ice (ice not used), and no freezing of the fish flesh.

Since no additional published information was found concerning utilization of the Bellefon–Falliot process, the assumption was made that the process did not meet with universal acceptance.

SUPERCHILLING IN PORTUGAL

The subject of superchilled fish storage then remained in the background until the IIR Congress in Munich. At this meeting, Ranken (1963) mentioned briefly that a system had been developed in Portugal to hold fish aboard a fishing vessel at about −1°C (30°F).

It was at the OECD meeting at Scheveningen in September 1964, however, that new interest and activity was generated on the superchill process for refrigeration of fish.

At that meeting, Scarlatti (1965) reported on the patented refrigeration system installed on some of the Portuguese fishing vessels. In the Scarlatti system, fish were bulk stored in divided compartments at a ratio of 0.3 to 0.4 kg (0.66 to 0.88 lb) of ice to 1 kg (2.2 lb) of fish. An extensive mechanical refrigeration set-up, which allows for uniform refrigeration throughout the mass, was used to chill and to maintain temperatures at −1° to −3°C (30.2° to 26.6°F) throughout the fish and ice mixture. At −1°C (30.2°F), the fish were reported to be perfectly fresh for 21 days, storage at −2°C (28.4°F), extended the period to over 25 days, and at −3°C (26.6°F), the fish were reported to have been kept for over 35 days, but had a tendency to harden.

Observations on the Portuguese system

Dr. J. M. Shewan and Mr. J. H. Merritt of the Torry Research Station visited Portugal to inspect and make observations concerning the quality of superchilled fish,

landed by the Portuguese side trawler *Goraz* (Anon., 1964b; White Fish Authority, 1964). They observed that the quality of the superchilled fish, reported to be 30 to 32 days old, was superior to that being landed by regular fishing vessels. They estimated that the temperature of the catch was well below −2°C and observed that freezing of the melt water in the hold made discharge of the fish difficult. (The same discharge difficulty was observed by us at the Technological Laboratory, Gloucester, Mass., during a preliminary superchilled haddock-ice experiment.) Shewan and Merritt also observed that the flesh of cut and thawed superchilled fish appeared soft and estimated that it would not be suitable for fillets and smoke cures.

INVESTIGATIONS IN THE UNITED KINGDOM

The Torry Research Station and the White Fish Authority have been leaders in the latest studies on superchilled fish storage (Anon., 1964a; Merritt, 1965; Merritt, Livingston and Shewan, 1966; White Fish Authority, 1964, 1965). They found that regular bulk storage of cod in melting ice gave a storage time to condemnation level of 15 to 16 days. At superchill storage temperatures from −2° to −1°C (28.4° to 30.2°F), the storage time could be extended by about seven days. A series of tests was conducted at Torry and aboard the research vessel *Sir William Hardy* in which cod were stored, with ice, as boxed fish rather than in bulk. Cooling to 0°C (32°F) was rapid, about 6 h, but subsequent flesh temperature change, to the −1° to −3°C (30.2° to 26.6°F) range, was slow. The results of these tests verified that keeping time could be extended by superchilled storage. There were some disadvantages, however. The fillets from the superchilled cod had a rough appearance, and there was an increase in drip loss. At −1°C (30.2°F) flesh temperature, the damage due to ice formation was insignificant and eating quality was acceptable after 20 days' storage. At −2°C (28.4°F) flesh temperature, damage was slight and the appearance of fillets and smoke cures was acceptable. Eating quality was borderline after 26 days' storage. At −3°C (26.6°F) flesh temperature, the damage was severe and the fish were unsuitable for filleting and smoking. Eating quality, however, was acceptable after 35 days' storage.

A general recommendation was made that superchilling should not normally be used for storage periods of less than 12 days.

The latest information received on superchilled storage work being conducted at the Torry Research Station was obtained from John Peters on his return from a field trip to Ireland, and also to Torry (Peters, 1967). His information was that present investigations are concerned with the frozen storage of fishery products prepared from superchilled fish. No results were available at the time of his visit.

INVESTIGATIONS IN THE FEDERAL REPUBLIC OF GERMANY

Studies were conducted by the Federal Research Center for Food Preservation, Karlsruhe, to determine how the patented Portuguese superchilling process would work on North Atlantic caught fish under North Atlantic conditions (Partmann, 1965). A German trawler, equipped with a patented superchilling hold, found that contrary to claims, the fish were partly frozen at −3° to −4°C (26.6° to 24.8°F) and no protective ice glaze was formed. The same results were obtained in trials conducted on shore. Partmann concluded, in his write up of the trials conducted in Germany, that iced fish stored at −3° to −4°C (26.6° to 24.8°F) has to be considered as frozen fish. Changes in quality due to certain chemical processes, such as protein denaturation, glycogen, ATP-breakdown, etc., react at a maximum during the early freezing stages. He recommended, therefore, that the superchill process should be operated at temperatures just above the onset of freezing.

INVESTIGATIONS IN CANADA

Studies were conducted at the Halifax Laboratory, Fisheries Research Board of Canada, Halifax, Nova Scotia, to determine the effect of superchilled storage on the quality of gutted, round cod (Power and Morton, 1965). The temperatures tried were in the range between −4° to −1°C (25° to 30°F). Two methods, storage with ice plus refrigeration to lower the temperature, and plain refrigerated air, were tried.

Ice storage at −2° to −1°C (28° to 30°F) extended the storage life about seven days in comparison to regular melting ice storage. Cod stored in air at −3°C (27°F) were found to be acceptable at 32 days when the fillets were baked and after 41 days when the fillets were fried. This points up an important factor, which is, that the method of preparation for eating is very important in the evaluation of flesh quality changes.

Refrigerated storage in air resulted in skin surface drying and moisture loss but assisted in preservation due to reduction of bacterial growth. After considerable storage time, the dry skin was difficult to remove. Undesirable texture changes, due to the slow freezing, also occurred. The following quote from Power and Morton (1965) briefly states an interesting opinion on superchilling:

> "Holding round cod at superchill temperatures results in trading a loss in physical quality of the product (texture) for longer freedom from bacterial spoilage."

INVESTIGATIONS IN THE UNITED STATES

At the U.S. Bureau of Commercial Fisheries Technological Laboratory, Gloucester, Mass., superchill storage tests were conducted using gutted round haddock (Tech. Lab., 1967). In one test, ice plus refrigeration was used to maintain temperatures in the range of −3° to −1°C (26.6° to 30.2°F). In subsequent tests refrigerated air only was used to maintain single superchilled temperatures (±0.5 degC), of −1°C (30°F), −2°C (28°F) and −3°C (26°F), in each storage space. Emphasis was placed on the fresh shelf life after periods of superchilled storage and on the frozen storage life of packaged products prepared from superchilled haddock.

Haddock stored at −3°C (26°F) and −2°C (28°F) yielded fillets that were judged to be of good to fair quality after 29 days of storage. Storage at −1°C (30°F) yielded haddock fillets that were edible up to 22 days. Steam cooking of the fillets, in covered pans, was the method of preparation for the taste tests.

Superchilled storage of haddock resulted in fillets having a very rough, broken, wet appearance. Haddock held for 12, 20 and 30 days at −2°C (28°F) could be held an additional six, five and four days, respectively, in melting ice. The edible quality of the fillets at the end of these combined storage periods was just fair. Frozen packaged fillets also were prepared after the above superchilled storage periods. The quality of all the samples was judged to be poor after storage at −17.8°C (0°F) for 30, 40 and 48 days. Taste panel comments on the thawed cooked samples were: "tough", "decomposed", "rancid", "dry", "ammoniacal" and "musty".

A recent test was made in which the haddock were cooled rapidly to −2°C (28°F) by immersion in a refrigerated brine or in a Freon mixture having a boiling point of −2°C. The results, after superchill storage periods followed by packaging, freezing and storage at −23.3°C (−10°F), were similar to the findings of the previous tests.

SUMMARY

A review of the available information concerning superchilled storage of fish shows that partial freezing of the fish flesh during storage is a major problem. The partial freezing which takes place slowly, results in poor flesh texture, poor appearance and excess drip in fillets prepared from superchilled fish. Despite these adverse changes, edible quality seems to hold up fairly well, especially if the fish are cooked by frying. The storage life of frozen packaged fillets prepared from superchilled fish is very short. Thus, it appears that unless partial freezing, or the adverse effects of partial freezing, can be overcome at the lower temperatures, the workable range for superchilled storage may be from 0°C (32°F) to just above the freezing point (about 0.6°C or 31°F) of fish flesh. Depending on circumstances, this small and very critical range may or may not be economically useful.

References

ANON. 1935 Holding fish without ice. *Fishg Gaz.*, **3.**

ANON. 1964a Superchilling—a report from the White Fish Authority. *J. Refrig.*, **9,** 10.

ANON. 1964b Extending shelf life of the catch. *Fishg News*, 18th September.

MERRITT, J H 1965 Superchilling on board trawlers. *Annex* 1965–5 *Bull. int. Inst. Refrig.*, p. 183.

MERRITT, J H, LIVINGSTON, I and SHEWAN, J M 1966 Superchilling of fish—the position today. *Mod. Refrig.*, **69**(818), 438–443.

PARTMANN, W 1965 Some experiences concerning superchilling of fish. *Annex* 1965–5 *Bull. int. Inst. Refrig.*, p. 191.

PETERS, J A 1967 U.S. Bureau of Commercial Fisheries Technological Laboratory, Gloucester, Mass. (Personal communication.)

POWER, H E and MORTON, M L 1965 *New Series Circular*, No. 23, Halifax Laboratory, Fisheries Research Board of Canada.

RANKEN, M B F 1963 Some recent advances in refrigeration machinery installations in fishing vessels. *Progress in Refrigeration Science and Technology*, International Institute of Refrigeration, Commission 8, 1773.

SCARLATTI, E 1965 System for preserving fresh fish on board deep-water vessels. In *Fish Handling and Preservation*, OECD, Paris, p. 57.

TECHNOLOGICAL LABORATORY 1967 U.S. Bureau of Commercial Fisheries, Gloucester, Mass. (Unpublished information.)

WHITE FISH AUTHORITY 1964 *R.D. Bulletin*, No. 2.

WHITE FISH AUTHORITY 1965 *Ibid.*, No. 16.

The Chemical and Physical Characteristics of Cod Stored at Superchill Temperatures

by H. E. Power, Margaret L. Morton and Ruth E. Sinclair

The chemical and physical characteristics of cod stored at superchill temperatures

Atlantic cod (*Gadus morhua* L.) were stored in −3°C (26.6°F) and −0.5°C (31.1°F) air with, and without ice. Changes in its physical, chemical and organoleptic characteristics affecting the storage life were noted. Fish stored in air without ice were dehydrated reaching a moisture content of 78.5 per cent after 35 days storage for fish stored at −3°C (26.6°F) and 66 per cent for fish stored at −0.5°C (31.1°F) after 29 days in storage. Fish stored in ice at these temperatures showed no dehydration.

Bacterial growth in fillets cut from fish stored in air was low. Those stored in ice showed greater bacterial growth, the plate count on the fillets reaching 290,000 colonies/g for fish stored at −3°C (26.6°F) and 980,000 for fish stored at −0.5°C (31.1°F).

With the exception of fish stored at −0.5°C (31.1°F) all fillets cut from fish held at superchill temperatures showed greater decrease in extractable protein nitrogen and increases in free fatty acid than either iced or frozen controls.

Oxidative rancidity, as measured by the thiobarbituric acid values, did not appear to be greater than for frozen fillets used as controls except for fish held at −0.5°C (31.1°F) for over 20 days.

Organoleptic assessment of superchill stored fish showed that a considerable increase in storage life was possible at this temperature over fish stored in melting ice. Storage life of fish stored in −3°C (26.6°F) and −0.5°C (31.1°F) air was between 21 and 31 days.

Caractéristiques chimiques et physiques de la morue soumise à l'entreposage frigorifique à basse température

De la morue de l'Atlantique (*Gadus morhua* L.) a été entreposée à l'air à −3°C et à −0,5°C, avec et sans glace. Les modifications de ses caractéristiques physiques, chimiques et organoleptiques affectant sa durée de conservation ont été notées. Le poisson entreposé à l'air sans glace a subi une déshydratation et la teneur en eau était de 78,5 pour cent après un entreposage de 35 jours pour le poisson entreposé à −3°C et de 66 pour cent après 29 jours pour le poisson entreposé à −0,5°C. Le poisson entreposé dans la glace à ces températures n'a montré aucun signe de déshydratation.

La prolifération bactérienne dans les filets découpés à partir du poisson entreposé à l'air était faible. Pour les filets des poissons entreposés dans la glace le développement bactérien était plus grand, la numération sur plaques atteignant 290.000 colonies/g pour le poisson entreposé à −3°C et 980.000 pour le poisson entreposé à −0,5°C.

A l'exception du poisson entreposé à −0,5°C, tous les filets découpés à partir de poissons maintenus à basse température présentaient une diminution de l'azote protéique extractible et une augmentation de la quantité d'acides gras libres plus grandes que pour les témoins entreposés dans la glace ou congelés.

Le rancissement par oxydation, mesuré d'après les indices de l'acide thiobarbiturique, n'apparaissait pas plus accentué que pour les filets congelés utilisés comme témoins, sauf pour le poisson maintenu à 0,5°C pendant plus de 20 jours.

L'évaluation organoleptique des poissons entreposés à basse température indiquait qu'il était possible d'augmenter dans une mesure considérable la durée de conservation à l'entreposage à cette température, par rapport à la durée de conservation du poisson entreposé dans la glace fondante. La durée de conservation à l'entreposage du poisson entreposé à l'air à −3°C et à −0,5°C était comprise entre 21 et 31 jours.

Las características químicas y físicas del bacalao almacenado a temperaturas de sobreenfriamiento

Se almacenó bacalao del Atlántico (*Gadus morhua* L.) en atmósfera de −3°C (26,6°F) y −0,5°C (31,1°F), con hielo y sin él. Se observaron los cambios en sus características físicas, químicas y organolépticas que influyen en el almacenamiento. Se deshidrató pescado almacenado en atmósfera sin hielo, alcanzando un contenido de humedad de 78,5 por ciento el mantenido a −3°C (26,6°F) después de 35 días de almacenamiento, y de 66 por ciento el mantenido a −0,5°C (31,1°F) después de 29 días de almacenamiento. El pescado almacenado en hielo a estas temperaturas no dio señales de deshidratación.

La proliferación bacteriana en los filetes cortados en pescado almacenado al aire fue baja. El almacenado en hielo mostró una mayor proliferación bacteriana, alcanzando el recuento en placas en los filetes 290.000 colonias/g en el caso del pescado almacenado a −3°C (26,6°F) y 980.000 en al caso del pescado almacenado a −0,5°C (31,1°F).

Con la excepción del pescado mantenido a −0,5°C (31,1°F), todos los filetes cortados en el pescado conservado a temperaturas de sobreenfriamiento mostraron una mayor disminución del nitrógeno proteínico extraible y un mayor incremento de los ácidos grasos libres que las muestras testigo en hielo o congeladas.

El enranciamiento por oxidación, medido por los valores de ácido tiobarbitúrico, no fue mayor que en el caso de los filetes congelados empleados como muestra testigo, excepto en el caso del pescado conservado a −0,5°C (31,1°F) durante más de 20 días.

La determinación organoléptica del pescado sobreenfriado almacenado indicó que era posible un aumento considerable del almacenamiento a esta temperatura en el caso de pescado almacenado en hielo fundente. El almacenamiento del pescado conservado en atmósfera de −3°C (26,6°F) y −0,5°C (31,1°F) osciló entre 21 y 31 días.

THE usual method of preserving catches of fish between the time the fish are caught and when they are landed by the fishing trawler, is to store the catch in crushed ice after gutting and washing. If the fish has been carefully handled and iced properly, it soon reaches a temperature close to that of melting ice. However, the handling conditions on some boats are such that the temperature of part or all of the catch may be higher, often exceeding 1.6°C (35°F). If the temperature of the catch can be kept near 0°C (32°F), the growth of bacteria and the biochemical changes which cause a loss in quality are slowed sufficiently that a storage life of up to 15 days can be expected.

Many workers have shown that as the storage temperature of fish is lowered, the storage life of the fish is increased. A reduction in storage temperature from 2.8°C (37°F) to −0.3°C (31.5°F) has been shown by Castell and MacCallum (1950) to result in doubling the keeping time for cod and haddock fillets. Spencer and Baines (1964) have shown that the spoilage rate for white fish was linear between −1°C (30.2°F) and 25°C (77°F) and could be expressed by the formula $U = V(1 + C\theta)$ where U is the rate of spoilage, V is the rate of spoilage at 0°C (32°F), C is a constant and θ is the storage temperature.

Recently, considerable interest has been shown in holding fish at temperatures 1 to 3 degC (1.8 to 5.5 degF)

below freezing to permit a lengthening of the keeping time without the costs of processing and freezing at sea. Storing fish at these temperatures is known as superchilling; however, it could be referred to more accurately as partial freezing. At these temperatures a part of the water contained in the muscle is frozen, the remainder being in liquid form. While freezing, the liquid in a fish muscle behaves very much like a 1.4 per cent solution of sodium chloride. As shown in table 1 the water frozen at different temperatures varies from approximately 19 per cent at −1°C (30.2°F) to 70 per cent at −3°C (26.6°F).

TABLE 1. APPROXIMATE PERCENTAGE OF WATER IN FISH MUSCLE FROZEN AT SUPERCHILL TEMPERATURES

Temperature (°C)	*Approximate percentage of water frozen in fish muscle**
−1	19
−2	55
−3	70
−4	76

* Based on data by Dieuzeide and Novella (1950), Finn (1934) and Mahadevan and Carter (1948).

While lowering the temperature of fish muscle to slightly below 0°C (32°F) reduces bacterial growth and delays bacterial spoilage, there are other effects which are not so desirable. Some of these changes take place at their maximum rate in this temperature range. These are changes in the *post-mortem* biochemical processes and include the breakdown of fats to free fatty acids, production of lactic acid from breakdown of glycogen and, perhaps most important of all, denaturation of the protein with its accompanying increase in drip and toughening of the texture of the cooked fish. Love and Elerian (1964) have shown that the rate of protein denaturation in fish frozen at −30°C (−22°F) is maximal at a storage temperature close to −1.5°C (29.3°F) possibly due to the increased concentration of tissue salts due to removal of water as ice. Lovern (1961) has indicated that the maximum rate of hydrolysis of lipids to free fatty acid takes place between −2.4°C (27.7°F) and −10°C (14°F). As with protein denaturation and lipid hydrolysis, glycolysis also appears to reach a maximum in this region. Sharp (1934) has shown that for haddock muscle the temperature at which glycolysis takes place at its maximum rate lies between −3° and −3.5°C (26.6° and 25.7°F). Again data published by Tomlinson, Jonas and Geiger (1963) suggest that in lingcod (*Ephiodon elongatus*) the maximum rate of lactic acid production is near −3°C (26.6°F).

The present work is intended to show the effect of storage in −0.5°C (31.1°F) and −3°C (26.6°F) air on the quality of Atlantic cod (*Gadus morhua* L.).

METHODS

Organoleptic evaluation of quality

Assessment of round fish and fillet. After removal from storage, the fish were examined both in the round state and after filleting for odour, firmness, extent of drying, discolouration of flesh and texture of raw flesh.

Taste panel evaluation of quality. Fillets cut from the round fish were baked in separate pans covered with aluminium foil in an oven at 260°C (500°F) for 12 min. The frozen control fillets were baked similarly, without prior thawing, for 20 min. The cooked fillets were served immediately in coded dishes and graded for taste, texture and overall grade. A total of 24 judgments were obtained for each sample. The method of scoring, commonly used in this laboratory for the organoleptic assessment of fresh and frozen fish has been described elsewhere (Dyer and Dyer, 1949).

Moisture

Samples between 15 and 30 g weight were dried to constant weight in a vacuum oven at 103°C (217°F) for from 24 to 48 h.

Bacterial counts

Bacterial counts were made by blending 100 g of fillet with 200 g of water in a sterile Waring blender for 1 min and then making six dilutions of this homogenate in distilled water. Single plates were poured from each dilution. The agar medium was tripticase glucose extract agar which has been found to be satisfactory for growing fish-spoiling bacteria. The plates were incubated for 72 h at 25°C (77°F) and all counts were made using a Quebec Colony Counter.

Free fatty acids (FFA)

Lipids. Lipids were extracted from 100 g samples of muscle according to the chloroform-methanol extraction procedure of Bligh and Dyer (1959).

Free fatty acids. Free fatty acids were determined on 10-ml aliquots of the chloroform layer of the lipid extract by adding 10 ml methanol and titrating potentiometrically to pH 10.0 with 0.03 N alcoholic sodium hydroxide. Chloroform–methanol blanks were run as a control. Free fatty acid was calculated as oleic acid and expressed as percentage of the extracted lipid.

Extractable protein nitrogen (EPN)

Extractable protein nitrogen was extracted from 22.5 g samples by the method of Dyer *et al.* (1950) and estimated by the method of Snow (1950).

Thiobarbituric acid value (TBA)

The thiobarbituric acid value, a measure of oxidative rancidity, was determined by the distillation procedure of Tarladgis *et al.* (1960).

Temperature measurement

Measurement of air and fish muscle temperatures were made by means of A.S.T.M. calibrated thermometers (−10° to +5°C range), calibrated copper-constantan thermocouples with a Honeywell Model 2715 potentiometer, and a specially calibrated Honeywell Brown Electronik temperature recorder. Temperature measurements should be accurate to ±0.1 degC (±0.18 degF).

EXPERIMENTAL

History of fish

The fish used in this experiment were Atlantic cod (*Gadus morhua* L.) between 45 and 65 cm in length. They were caught by a shore fisherman at the village of Terrance Bay near Halifax, N.S., and brought alive to the laboratory where they were held in tanks for from one to three days until required. The fish were killed, eviscerated, headed and washed before being placed in storage at superchill temperature. Samples were withdrawn for quality evaluation at semi-weekly intervals during the latter part.

Storage conditions

The eviscerated, headed and washed fish were stored in constant temperature cabinets inside a cold room held at −12°C (10°F). Electric heaters inside the cabinet were controlled by means of a time proportioning "Versatran" temperature control R7113C made by Honeywell Controls Ltd., Toronto, Ontario. The sensing element is a thermistor in a Wheatstone bridge circuit. The walls were partly jacketed and the air was circulated by means of a fan. The heat input could be balanced with requirement at each temperature by varying the voltage to the heating units with a variable voltage transformer.

Storage temperature. Fish were stored under five different storage conditions as listed below:

(1) The first lot of fish was stored in −3°C (26.6°F) air without ice, on wire-mesh screens after having been pre-chilled to −3°C (26.6°F). Pre-chilling was carried out by placing the fish in shallow aluminium pans in −11.4°C (11.5°F) air until a thermocouple placed 1 cm beneath the skin of the fish, near the thickest part, showed that the temperature in this area had reached −3°C (26.6°F). The fish was then transferred to the −3°C (26.6°F) constant temperature cabinets.

(2) The second lot of fish was stored in −3°C (26.6°F) air without ice, on wire-mesh screens immediately after processing without pre-chilling.

(3) Lot (3) was stored in −3°C (26.6°F) air in crushed ice in metal boxes without pre-chilling.

(4) Lot (4) was stored in −0.5°C (31.1°F) air, without ice on wire-mesh screens without pre-chilling.

(5) Lot (5) was stored in −0.5°C (31.1°F) air in crushed ice in metal boxes without pre-chilling.

(6) Unfrozen fish used for controls were stored in melting ice after eviscerating and washing.

(7) Frozen controls were fillets frozen *post-rigor* at −40°C (−40°F) in a plate freezer in individual waxed cartons and stored at −26°C (−15°F).

Temperatures of fish muscle during storage. Although the samples were stored in air at either −3°C (26.6°F) or −0.5°C (31.1°F), the temperature of the muscle during storage was lower than the air temperature. The temperature of the muscle tends to approach the wet bulb temperature of the air which in turn depends on the humidity of the air in the storage box. The humidity of the air depends both on its temperature and on the amount of moisture removed by the refrigeration system. The actual temperatures of the fish muscle during storage are noted below:

(1) Lot (1) had an initial temperature of approximately 9°C (48.2°F) and after processing was placed in aluminium pans in still air at −11.4°C (+11.5°F) and chilled until thermocouples 1 cm beneath skin reached −3°C (26.6°F). This required 10 h. After being placed in the −3°C controlled temperature cabinet the temperature of the muscle continued to drop slowly to a low of −3.8°C (25.1°F) at 11 days after which it increased steadily reaching −3.2°C (26.2°F) at the end of 35 days' storage.

(2) Lot (2), stored in −3°C (26.6°F) air without ice or pre-chilling, started with an average initial temperature of 12.8°C (55°F) falling within 4 h to 0.1°C (32.2°F) and to −4°C in four days. The temperature then rose to between −3.6° and −3.8°C (25.5° and 25.2°F) where it remained until the experiment ended at 35 days.

(3) Lot (3), which was stored in −3°C (26.6°F) air in crushed ice, dropped from an initial temperature of 10.8°C (51.4°F) in 4 h to −0.5°C (31.1°F) and to −1.2°C (29.8°F) at 11 h. From this point the temperature of the muscle dropped at a steady rate to −3.6°C (25.5°F) at 27 days where it remained until the end of the experiment at 35 days.

(4) Lot (4), stored in −0.5°C (31.1°F) air on screens and without ice, dropped in temperature from 6.4°C (43.5°F) to −0.5°C (31.1°F) in 4 h, to −0.8°C (30.6°F) in 12 h reaching −1.0°C (30.2°F) in 24 h. After five days' storage the temperature of the muscle reached a low of −1.8°C (28.8°F) from which it increased to −1.7°C (28.9°F) at the end of the experiment at 29 days.

(5) Lot (5), stored in −0.5°C (31.1°F) in ice, dropped in temperature from an initial temperature of approximately 5°C (41°F) to −0.4°C (31.3°F) in 16 h. After 24 h storage the temperature was −0.5°C (31.1°F) and after 48 h the temperature had reached −0.6°C (30.9°F). At eight days the temperature had lowered to −0.7°C (30.7°F) and at 14 days it reached −1.1°C (30°F) where it remained until the end of the experiment.

RESULTS

Physical changes in round fish and fillets

Dehydration during storage. The average moisture contents of fillets cut from cod stored in air with and without ice are shown in fig 1. The fillets cut from fish stored in crushed ice showed no loss in moisture over the storage

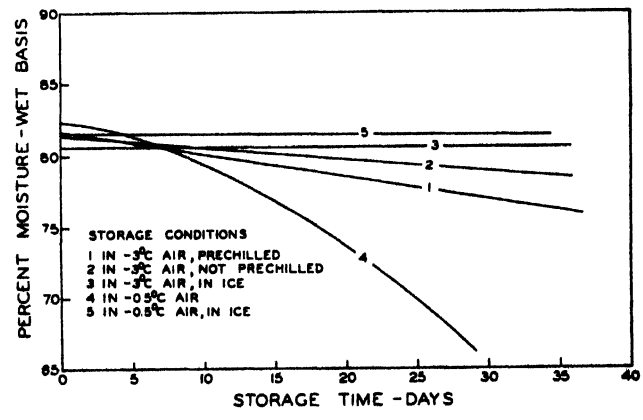


Fig 1. Changes in moisture content of fillets cut from cod stored at superchill temperatures

period. However, when the fish were stored on wire screening, without ice, the amount of moisture loss was considerable. The fish stored in −3°C (26.6°F) air was gradually dehydrated reaching a value of 78.5 per cent moisture after 35 days' storage. The fish which were pre-chilled before storing in −3°C (26.6°F) air were dehydrated to an even greater extent, the moisture content falling from an initial value of 82 to 76 per cent in 35 days. Fish stored in −0.5°C (31.1°F) air without ice were dehydrated at a much greater rate, the moisture content falling to 66 per cent after 29 days' storage.

Appearance and odour changes in round fish and raw fillets. Cod stored in −3°C (26.6°F) air without ice showed a pattern of physical changes which differed from that of fish held in melting ice. The skin of the fish became first sticky, then dry, and finally very dry and wrinkled as storage progressed. The fillets showed a tendency to adhere to the skin as drying progressed. After five weeks' storage a layer of dry flesh approximately 3 mm thick was formed just under the skin. Drying was particularly marked in the nape and tail. The tail eventually became brittle, the nape and later the cut belly flaps became first spongy, then hard. The sponginess was accompanied by a progressive yellowing of the flesh at the cut surface after 10 days' storage. In some cases there was discolouration around the backbone and gut cavity which extended into the fillet. Changes in the fillet, due to dehydration, were not evident until surface drying in the round fish was well advanced. However, the texture of the raw fillet became coarse during storage and ice crystals were visible in the fillets after the fifth day of storage. Ice crystals were also visible in the gut cavity after two to three weeks of storage. Odours were non-existent or very slightly fishy until after four weeks' storage and slightly fishy between four and six weeks in storage. These characteristics are detailed in tables 2 and 3.

When cod were stored in ice, in −3°C (26.6°F) air, the surface remained slimy during the whole storage period. The flesh was never frozen hard and became softer as time in storage increased. After six weeks' storage the surface of the fish was easily dented and was seriously marked by the ice in which the fish was stored. The cut surface of the fish at the napes was beginning to yellow at three weeks and by six weeks' storage the napes were yellow. A large amount of ice adhered to the gut cavity throughout the storage period.

After two weeks' storage the texture of the raw fillet began to change from normal iced texture to a much coarser texture. At four weeks the texture was both coarse and soft with a ragged appearance. When cooked there was a large amount of drip and the fillet fell apart at the myotomes.

The round fish developed a slightly fishy odour after two weeks' storage which developed to a fishy, stale odour after three weeks and became stronger as storage progressed. A slight fishy-stale odour was noticeable on the fillet at three weeks. This odour became stronger with storage until at six weeks it became very offensive during cooking. An outline of these changes in the round fish is given in table 4.

TABLE 2. PHYSICAL CHARACTERISTICS OF ROUND MARKET COD FISH STORED IN −3°C AIR AFTER PRE-CHILLING TO −3°C IN −12°C AIR

Characteristics	*Storage time (weeks)*					
	1	2	3	4	5	6
Odour	None	None to slightly fishy	None to slightly fishy	None to slightly fishy	Slightly fishy	Slightly fishy
Tail and fins	Sticky-drying, not brittle	Dry, brittle AT/TIP	Dry	Dry, brittle	Dry	Dry, brittle
Skin before thawing	Sticky-drying	Dry	Dry, slightly wrinkled	Dry	Dry	Dry, wrinkled
Skin after thawing	Slimy	Non-adherent slime	Non-adherent slime Skin sticks to fillet	Progressively tougher	Progressively tougher	Difficult to fillet, dry layer approximately 3 cm thick
Nape	Normal-drying	Drying, yellowing (especially near back bone), slightly spongy	Dry, yellow spongy	Yellow, dry spongy	Yellow, dry spongy	Yellow, dry spongy, hard
Fillet	Slightly fibrous, slightly coarse	Slightly coarse, "slushy"	Coarse, "slushy" ice crystals	Coarse, ice crystals	Coarse	Fibrous
Gut cavity	Small ice crystals	Small ice crystals	Small ice crystals	Small ice crystals		

TABLE 3. PHYSICAL CHARACTERISTICS OF ROUND MARKET COD FISH STORED IN −3°C AIR WITHOUT PRE-CHILLING

Characteristics	*Storage time (weeks)*				
	1	2	3	4	5
Odour	None	Very slightly fishy	Very slightly fishy	Slightly stale	Slightly fishy
Tail and fins	Slightly dry	Dry, not brittle	Brittle	Brittle	Brittle
Skin	Smooth, not sticky, dentable	Dry, when thawed, slime non-adherent	Dry, thicker, non-adherent slime slightly more difficult to remove	Dry, tough, non-adherent slime difficult to remove	Dry, tough, thick, very difficult to skin
Nape	Approximately quarter dried	Slightly yellow, slightly dry	Dried, slightly yellow	Yellowed, dry	Dry, yellowed
Fillet	Normal	Normal, slightly coarse	Coarsened	Slightly coarse	Coarse

TABLE 4. PHYSICAL CHARACTERISTICS OF ROUND MARKET COD FISH AND FILLETS STORED IN ICE IN −3°C AIR WITHOUT PRE-CHILLING

Characteristics	*Storage time (weeks)*					
	1	2	3	4	5	6
Odour	None	Slightly fishy	Slightly fishy, stale	Slightly fishy, stale	Slightly stale	Fishy, stale
Skin	Slimy	Dents to pressure, slimy when thawed	Dents to pressure, slimy before and after thawing	Soft, dentable, slimy before and after thawing	Soft, dents easily, slimy before and after thawing, skin slightly thicker	Very soft, slimy, very slimy after skinning
Nape	No discolouration	No discolouration	Yellowing	Slightly yellowed	Slightly yellowed	Slightly yellowed
Fillet	Normal	Coarsened texture	Coarse	Coarse, slightly soft	Coarse, soft	Very soft, coarse, much cooking drip
Gut cavity	Large amount of ice clinging to gut cavity throughout					

Round fish stored in −0.5°C (31.1°F) air without ice remained odourless for two weeks and had a very slight fishy odour after four weeks' storage. The fillets cut from these fish remained of good appearance for over two weeks. At three weeks it was still firm and odourless, but the texture had become slightly coarse containing ice crystals up to 3 mm long. It had also become slightly yellow in colour. The skin, however, became progressively thicker and tougher. At two weeks the fillets had become difficult to skin and from three weeks on they were very difficult to skin with a marked reduction in fillet yield. These changes in physical characteristics are shown in table 5.

The round cod stored in −0.5°C (31.1°F) air in ice developed a slightly fishy odour after the first week in storage. This odour became progressively stronger during the storage period becoming a very stale, fishy odour after the fourth week. The skin was slightly slimy after one week of storage. It became slimy during the second week of storage and remained in this condition until the end of the experiment. The gut cavity also developed a slightly fishy stale odour after one week's storage which became very stale after four weeks.

The raw fillet had no odour after one week's storage. This became very slightly fishy after two weeks' storage becoming fishy after four weeks. The texture remained normal and firm until the second week of storage when it became soft and ragged in appearance.

Bacterial counts on fillet

Bacterial plate counts made on the fillets cut from super-chilled fish are shown in table 7. All samples in air, without ice, showed very little growth in bacteria population, the maximum figure being 6,200 colonies per gram of

TABLE 5. PHYSICAL CHARACTERISTICS OF ROUND MARKET COD FISH AND FILLET STORED IN −0.5°C AIR (WITHOUT PRE-CHILLING)

Characteristics	1	2	3	4
Round fish				
Odour	None	None	Very slightly fishy	Slightly fishy
Tail and fins	Brittle	Brittle	Brittle	Brittle
Skin	Dry	Dry, toughened	Dry, toughened	Tough, brittle
Nape	Very slightly yellow	Slightly yellow	Yellow, somewhat dried	Yellowed, dried
Ease of skinning	Slightly difficult	Difficult	Very difficult*	Very difficult*
Fillet				
Odour	None	None	None	Slightly fishy
Colour	Normal	Normal	Slightly yellowed	Yellowed
Texture	Very slightly coarsened	Coarsened, ice crystals ¼ in long	Coarsened	Coarsened, dry

* Filleting gave low yield—impractical from commercial point of view.

TABLE 6. PHYSICAL CHARACTERISTICS OF ROUND MARKET COD FISH—STORED IN −0.5°C AIR IN ICE

Characteristics	1	2	3	4
Round Fish				
Odour	Slightly fishy	Fishy	Stale fishy	Very stale fishy
Tail and fins	Beginning to lose suppleness	Slightly brittle	Brittle	Brittle
Skin	Slightly slimy	Slimy	Slimy	Slimy
Nape	Very slightly yellowing	Yellowing	Yellow, drying	Yellow, dry
Ease of skinning	Normal	Normal	Normal	Normal
Gut cavity	Slightly fishy odour	Stale fishy odour	Stale odour	Very stale odour
Fillet				
Odour	None	Very slightly fishy	Slightly fishy	Fishy
Colour	Normal	Normal	Slightly yellowing	Slightly yellowing
Texture	Normal, firm, very small ice crystals	Soft and ragged, ice crystals	Soft and ragged, ice crystals	Soft and ragged, ice crystals

Above descriptions do not include some fish which were lying in water. These were soft, had slimy skin, supple tail and fins, fishy odour—soft fillet, no ice crystals, very slightly yellowing. On 13, 16 and 20 days, one of these and one of above were used for taste panel and other tests.

Consumer would reject fish at three weeks due to ammonia odour from cooking fumes.

TABLE 7. BACTERIAL PLATE COUNTS PER GRAM OF COD FILLET AFTER STORAGE AT SUPERCHILL TEMPERATURES

Time (days)	*Frozen control*	*Storage conditions*				
		Pre-chilled, in −3°C (26.6°F) air	*In −3°C (26.6°F) air*	*In −3°C (26.6°F) air, in ice*	*In −0.5°C (31.1°F) air*	*In −0.5°C (31.1°F) air, in ice*
0	7,500	—	—	—	—	—
1	—	—	—	900	—	177,000
2	3,300	0	750	—	600	—
4	—	—	0	300	—	—
6	—	—	—	—	—	—
8	—	—	600	0	—	1,000
9	6,900	100	—	—	0	—
13	—	—	240	240	—	—
15	—	100	—	—	—	45,000
16	4,200	—	—	—	0	—
17	—	300	—	—	—	—
18	—	6,200	—	—	—	—
19	—	—	240	240	—	—
20	—	—	—	—	—	18,000
22	—	—	4,500	3,900	—	—
29	5,100	—	0	—	0	—
30	—	—	—	—	—	980,000
31	—	500	—	—	—	—
36	—	—	0	296,000	—	—
37	—	500	—	—	—	—

fillet. Counts made on frozen control fillets stored at −26°C (−10°F) were between 3,300 and 6,900 colonies per gram. In the case of fish stored in ice there was increased bacterial growth. The bacterial population appeared to drop during the first week's storage and then increased slowly to a value of 980,000 at 30 days when stored in −0.5°C (31.1°F) air and 296,000 for the fish stored in −3°C (26.6°F) air at 36 days.

Thiobarbituric acid values

The thiobarbituric acid values were measured on 100 g samples of muscle from the head end of the fillet. Generally, the TBA values of fillets stored in −3°C (26.6°F) were low, being between 0.017 and 0.061, except for two samples with values of 0.136 and 0.112, the first occurring after one day's storage in air without ice, and the second value after 10 days' storage under the same condition. There did not appear to be any increase in TBA values with storage time. Cod fillets frozen *post-rigor* at −40°C (−40°F) and stored in waxed cartons at −26°C (−15°F) had TBA values between 0.023 and 0.077 during the storage period with no apparent correlation between storage time and TBA values.

The samples stored in −0.5°C (31.1°F) air and in −0.5°C air in ice showed no increase in TBA values until just before the sample became unacceptable to the taste panel when the TBA values increased slightly. The TBA values of fish stored in air only were between 0.033 and 0.068 until after 22 days' storage when the value increased to 0.090. The samples stored in ice had TBA values between 0.021 and 0.036 until the 26th day of storage when the value increased to 0.072.

Extractable protein nitrogen changes

The rate of protein denaturation as measured by the percentage of extractable protein nitrogen varied over a wide range depending upon storage conditions. The EPN in fillets of fish which had been held in −3°C (26.6°F) air without ice dropped rapidly after the first week in storage. The samples which had been pre-chilled levelled off at a value of 40 per cent after approximately two weeks' storage and then continued to decrease to a value of 25 per cent of the total protein after 37 days' storage. The fish which, although stored under the same conditions, had not been pre-chilled, dropped to a level of approximately 20 per cent after three weeks' storage which was maintained until the end of the experiment. The sample which had been stored in −3°C (26.6°F) air in ice showed a steady decline in EPN from an initial value of 94 per cent to a low of 32 per cent after 35 days' storage.

Of the samples stored in −0.5°C (31.1°F) air, the one stored without ice showed a steady decline in EPN during the storage period to a value of 35 per cent after 30 days. The sample in −0.5°C (31.1°F) air, in ice, showed no decrease in EPN over the storage period. The changes in EPN for all samples are shown in fig 2.

Lipid hydrolysis

All samples stored at superchill temperature showed an increase in the percentage of lipid hydrolyzed to free fatty acid during the storage period. The fish stored in air, without the protection of ice, showed the greatest increase in FFA. Storage in −3°C (26.6°F) air after pre-chilling resulted in the most rapid increase in FFA.

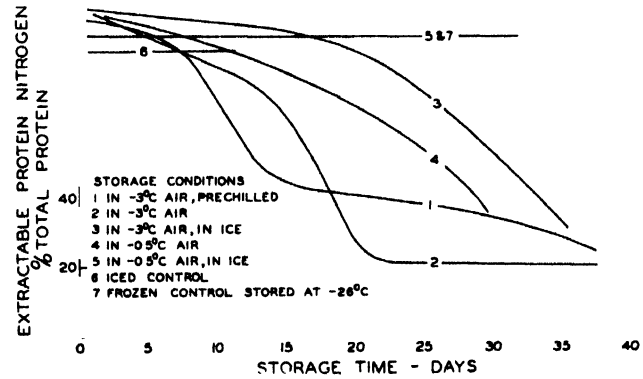


Fig 2. Extractable protein nitrogen in fillets from cod stored at superchill temperatures

This increase in FFA began immediately after the fish were placed in storage and after five days had reached a value of 27 per cent of the lipid, and it continued to increase until at 35 days 64 per cent of the lipid had been hydrolyzed. Fish stored under identical conditions except that it was not pre-chilled to −3°C (26.6°F) showed a similar increase in FFA with two exceptions, the rapid increase in FFA did not begin immediately but only after a week in storage. At one week the FFA was 18 per cent, while after two weeks it had reached 42 per cent of the lipid. After 20 days' storage the increase stopped and the FFA remained near 50 per cent of the lipid for the remainder of the storage period. When stored in ice in −3°C (26.6°F) air the rate of lipid hydrolysis was much lower, reaching a value of 30 per cent of the lipid after 35 days in storage.

Of the samples held in −0.5°C (31.1°F) air, the one held in air only showed a rapid increase in FFA after the first week's storage when the FFA rose to 34 per cent at 6 days' storage and continued to increase at a much lower rate during continued storage, reaching 42 per cent of the lipid after 35 days' storage. Samples stored in ice showed a much more gradual increase in rate of lipid hydrolysis, with the percentage of FFA reaching 30 per cent after 30 days' storage. Fig 3 shows changes in FFA content after various periods of storage at superchill temperatures for cod.

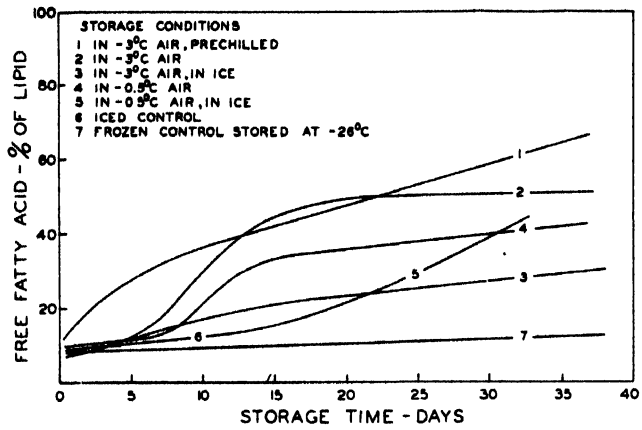


Fig 3. Free fatty acid in fillets from cod stored at superchill temperatures

Taste panel assessment of cooked fillets

For organoleptic assessment of quality, whole fillets, cut from superchilled round fish were baked at 260°C (500°F) and served to the taste panel without condiments. They were graded for texture, taste, odour and overall quality. Controls used were frozen cod of top quality and cod stored in melting ice. With the numerical scoring system used, a score of 100 indicated a perfect sample, and 0 a very badly spoiled one. A score below 40 denoted that the sample was unacceptable. The taste panel scores for fish stored at superchill temperatures are shown in figs 4, 5 and 6.

Cod pre-chilled to −3°C (26.6°F) and then stored in −3°C air dropped rapidly in texture scores from initial values near 80 to just above the level where they would

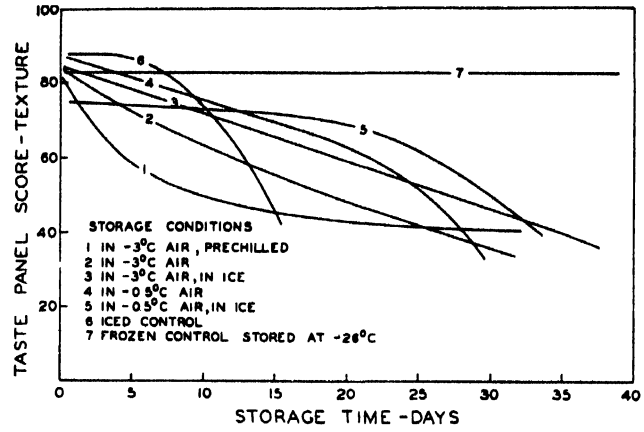


Fig 4. Taste panel scores of texture of cod stored at superchill temperatures

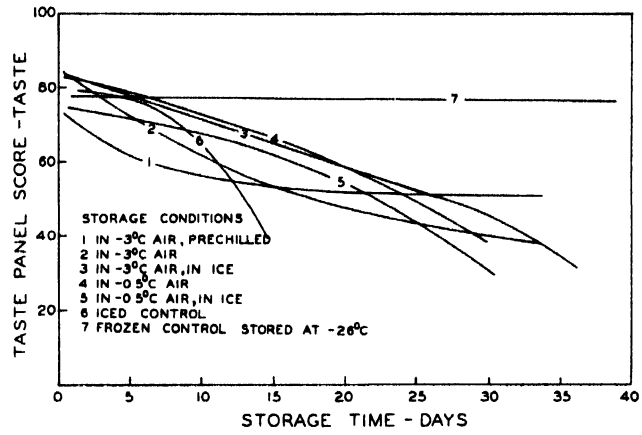


Fig 5. Taste panel scores of taste of cod stored at superchill temperatures

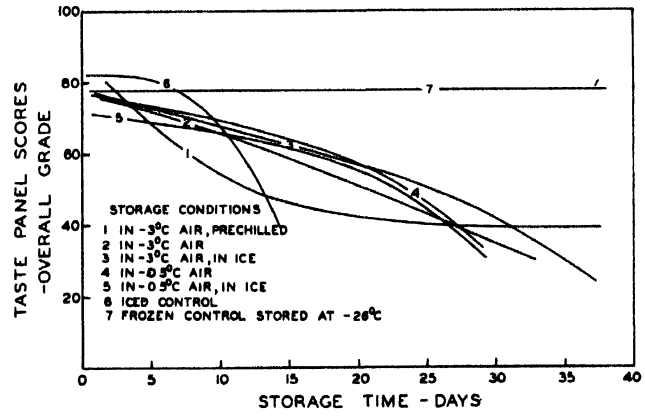


Fig 6. Taste panel scores of overall grade for cod stored at superchill temperatures

It maintained this quality level until after 32 days' storage when it was graded as unacceptable. The scores for taste and overall grade also dropped rapidly initially, levelling off after 15 days' storage with grades of 52 for taste and approximately 40 for the overall grade. These scores were maintained until the experiment was discontinued at 37 days. Texture changes were characterized by increasing toughness, coarseness, stringiness

gradually decreased due to the development of off-flavours similar to those found in spoiling iced fish.

Samples stored under the same conditions without pre-chilling showed a more gradual loss in quality, the loss being almost proportional to storage time. These fish follow the normal spoilage pattern found with fish stored in melting ice. The texture, firm and tender at the beginning of the storage period, became mushy, stringy, tough and coarse as storage progressed. The taste passed through a stage where the fish was tasteless and later became stale and fishy. The taste panel found this fish unacceptable after 27 days' storage.

The fish stored in −3°C (26.6°F) air in ice, and in −0.5°C (31.1°F) air with and without ice showed a gradual decline in taste panel scores for texture, taste and overall grade being rejected by the taste panel after 31, 26 and 26 days' storage respectively. With the exception of the samples stored in −0.5°C air in ice all followed a spoilage pattern similar to that of cod stored in melting ice. The texture progressed from firm, tender and moist through mushy to stringy and coarse. The taste and odour became neutral and then stale and fishy. Although the taste panel rejected the sample stored in −0.5°C (31.1°F) air, in ice, after 26 days' storage, the housewife who cooks the fish would undoubtedly have rejected it at 20 to 21 days as during cooking the odour of ammonia was noticed.

Samples of cod held in melting ice, used for control, were rejected by the panel after 14 days' storage.

SUMMARY

Storage life of superchilled cod as determined by taste panel evaluation

Although storage at superchill temperatures extends the storage life of cod to approximately twice that of fish stored in melting ice, initially the quality is inferior to iced fish. Superchilled fish is rated lower in quality than iced fish until after nine days' storage. The advantages of superchilled storage are in the lower rate of deterioration from nine days' storage to 26 to 32 days when the superchilled fish became unacceptable.

Cod which had been pre-chilled showed a rapid drop in quality during the first two weeks of storage. This was followed by a levelling off of the taste panel scores at the borderline level. This rapid drop in quality is probably the result of the outside surface of the fish approaching the temperature of the air used for pre-chilling (−11.4°C, 11.5°F) and then being warmed to the −3°C (26.6°F) storage temperature with melting of part of the water which had been frozen during pre-chilling. When cooked by frying, which tends to mask flavour and texture changes (Dyer *et al.*, 1964) one sample of this fish was of acceptable quality after 41 days' storage. None of the samples not pre-chilled showed this rapid initial drop in quality or the subsequent levelling off of the quality after two weeks of storage.

Generally the texture of cooked superchilled fish followed the changes which normally occur with fish stored in melting ice, progressing from firm tender, moist to coarseness, stringiness and toughness. However, one lot, that stored in −0.5°C (31.1°F) air, in ice, initially had a soft texture which was maintained for three weeks subsequently becoming mushy and mealy rather than coarse and tough. This sample also showed no decrease in extractable protein nitrogen during its storage life.

Moisture loss during storage

Dehydration of fish stored in air, without ice, is a serious problem likely to make this type of storage unacceptable to commercial fish processors. From initial values between 80.5 and 82.5 per cent the samples stored in air were reduced in moisture content to 78.5 per cent for fish stored in −3°C (26.6°F) air at 35 days and 66 per cent for fish stored in −0.5°C (31.1°F) air at 29 days. This difference can be accounted for by the difference in storage temperature and the reduced amount of liquid frozen in the muscle of the fish stored at the higher temperatures. In addition to the economic losses likely to be caused by the weight loss of the fish, dehydration caused difficulties in skinning with reduced yield due to thickening of the layer of muscle adhering to the skin. These problems were not encountered in fish stored in ice.

Bacterial growth during storage

Counts made on the fillets cut from cod stored at superchill temperatures are in general low. There appears to be a reduction in the bacterial population during the first week of storage followed by an increase in the case of fish stored in ice. Pivnick has shown (1949) that freezing of fish muscle for 24 h causes a decrease in the bacterial population of from 40 to 60 per cent. Storage of the frozen muscle resulted in further population decreases with the death rate being higher at a storage temperature of −12.2°C (10°F) than at −23°C (−10°F). It appears that storage of round fish at superchill temperatures results in an initial decrease in the bacterial population. Growth of bacteria was inhibited during storage in fish held in air due to the lower temperature, compared to iced fish, and also apparently by drying of the surface of the fish. On fish stored in ice where the surface was kept moist, the counts reached 296,000 for fillets of fish stored in −3°C (26.6°F) air and 980,000 for fillets of fish stored in −0.5°C (31.1°F) air.

Rancidity

Rancidity is not normally a problem with frozen cod fillets or with fillets stored at melting ice temperature. It does not appear that rancidity will be a problem with fish stored at superchill temperatures. Until the cooked fillets were found unacceptable by the taste panel, there was no increase in rancidity, as measured by the TBA value, with storage. The TBA values for superchilled fish were of the same magnitude as those of the frozen fish used as controls.

Castell *et al.* (1966) have suggested a relationship between the production of free fatty acid in the muscle and the resistance to oxidative rancidity of the lipids. This is a possible explanation for the oxidative stability of the lipids of fish held just below the freezing point where the rate of lipid hydrolysis is near its maximum.

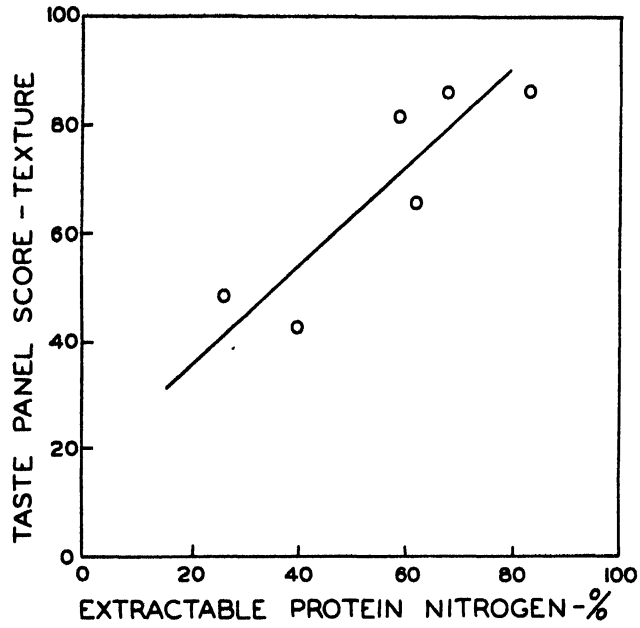


Fig 7. Taste panel scores for texture plotted against per cent EPN for cod stored at superchill temperatures for 20 days

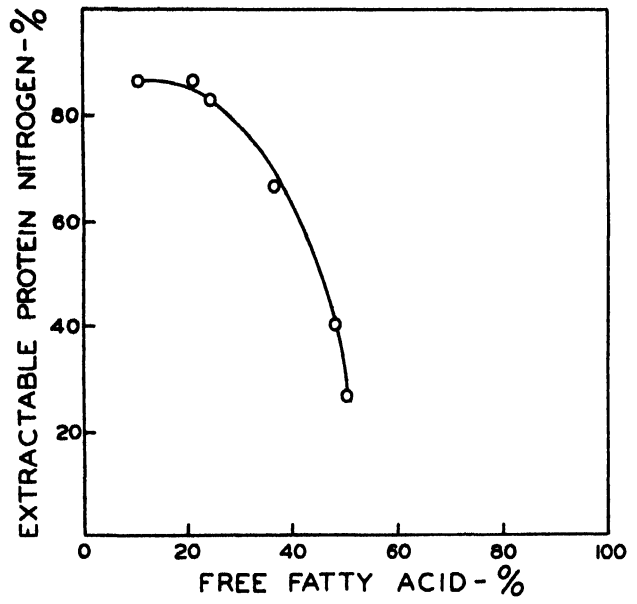


Fig 8. Taste panel scores for texture plotted against per cent EPN for cod stored at superchill temperatures for 20 days

Changes in extractable protein nitrogen and lipid hydrolysis

Measurement of the amount of protein extractable with sodium chloride solution indicates that the rate of protein denaturation is greater for fish stored in air without ice where dehydration is an additional factor. Samples stored in ice show a lesser amount of protein denaturation. There is also a temperature effect with the samples stored at the lower temperature having a greater amount of denaturation than those stored in −0.5°C (31.1°F). air. A relationship between EPN and taste panel texture scores was shown by Dyer (1951) for frozen cod fillets. This relationship is apparent in taste panel evaluation of superchilled cod as shown in fig 7. As the amount of extractable protein nitrogen decreases, the taste panel texture scores also decrease proportionately. Again, the relationship between lipid hydrolysis and extractable protein nitrogen suggested by Dyer and Fraser (1959) is in evidence. In fig 8 the FFA is plotted against EPN for fish after 20 days' storage, showing a decrease in EPN or increase in protein denaturation as the lipid is hydrolized to free fatty acid.

CONCLUSIONS

Reducing the storage temperature of round cod to just below the point where the water in the muscle begins to freeze can increase the storage life, as measured by a taste panel, from approximately 14 days to between 26 and 31 days. Storage of fish in air without ice causes dehydration which, due to processing difficulties and reduced yield, would make this method of storage unacceptable for commercial use. Storage in ice, in −3°C (26.6°F) and −0.5°C (31.1°F) air, caused no dehydration and in the case of fish stored in −3°C air, cooked fillets were acceptable after 31 days' storage although the texture was soft and coarse. When stored in −0.5°C air, in ice, the taste panel found the cooked fillets acceptable after 26 days' storage; however, the commercial storage life of this fish would probably be limited to approximately 21 days due to development of ammonia odours on cooking and slight yellowing of the uncooked fillet.

References

BLIGH, E G and DYER, W J *Can. J. Biochem. Physiol.*, **37**, 1959 911–917.

CASTELL, C H and MACCALLUM, W A *J. Fish. Res. Bd Can.*, 1950 **8**, 2.

CASTELL, C H, MOORE, B A, JANGAARD, P M and NEAL, 1966 WANDA E *Ibid.*, **23**, 9.

DIEUZEIDE, R and NOVELLA, M *La technique de la conservation* 1950 *par le froid des poissons et autres animaux marins comestibles.* Alger, 41 rue Mogador, V. Heintz, 175 pp.

DYER, F E and DYER, W J *J. Fish. Res. Bd Can.*, **7**, 449–460. 1949

DYER, W J *Fd Res.*, **16**, 522–527. 1951

DYER, W J and FRASER, D I *J. Fish. Res. Bd Can.*, **16**, 43–52. 1959

DYER, W J, FRASER, D I, MACINTOSH, R G and MYER, M 1964 *Ibid.*, **21**, 577–589.

FINN, D B *Contr. Can. Biol. Fish.*, **8**, 313–320. 1934

LOVE, R M and ELERIAN, M K *J. Sci. Fd Agric.*, **15**, 11. 1964

LOVERN, J A The lipids of fish and changes occurring in 1961 them during processing and storage. In *Fish in Nutrition*, ed. E. Heen and R. Kreuzer, Fishing News (Books) Ltd., London, p. 86.

MAHADEVAN, V and CARTER, N M *Prog. Rep. Pacif. Cst Stns*, 1948 No. 76, 85–87.

PIVNICK, H Thesis submitted to Dalhousie University, 1949 Halifax, Nova Scotia.

SHARP, J G *Rep. Fd Invest. Bd.*, HMSO, London, 96 pp. 1934

SPENCER, R and BAINES, C R *Fd Technol.* **18**(5), 175. 1964

SNOW, J M *J. Fish. Res. Bd Can.*, **7**, 10. 1950

TARLADGIS, B G, WATT, BETTY M, YOUNATHAN, MARGARET T 1960 and DUGAN, L *J. Am. Oil Chem. Soc.*, **34**, 44–48.

TOMLINSON, N, JONAS, R E E and GEIGER, S E *J. Fish. Res.* 1963 *Bd Can.*, **20**(5).

Partial Freezing of Pacific Salmon Intended for Canning

by S. W. Roach and N. Tomlinson

Partial freezing of Pacific salmon intended for canning

In British Columbia Pacific salmon accounts for approximately 55 per cent of the landed value of all species. Refrigerated sea water is extensively used for preserving salmon during transport from fishing grounds to canneries and yields an acceptable canned product from uneviscerated non-feeding salmon even after 14 days. However, adverse quality changes become increasingly evident after seven days.

The possibility that undesirable changes may be prevented by partially freezing and storing the fish in salt-reinforced sea water has been investigated. Salmon were held at −4°C (25°F) for two weeks without the appearance of belly-burn or bacterial spoilage. Darkening of flesh adjacent to the visceral cavity from the diffusion of pigment from kidney, liver and spleen was prevented. Lipid from red lateral muscle was found very susceptible to rancidity but this defect was overcome by sealing the storage tank. The decrease in free oil in canned salmon after partial freezing has been investigated.

Partially-frozen salmon were compared with fish stored unfrozen in refrigerated sea water. Weight changes during storage were small. Spoilage odours developed during storage in unfrozen fish but not in fish partially frozen. Sodium uptake and potassium losses were similar, but magnesium uptake was less in partially-frozen fish.

Partial freezing of salmon in this manner, while not ideal, provides a practical method of storage for up to 17 days. Quality of the canned product was judged from organoleptic tests, including colour, curd formation, firmness of flesh, quantity of free oil and odour.

Congélation partielle du saumon du Pacifique destiné à la conservation en recipients hermetiques

En Colombie britannique, le saumon représente à peu près 55 pour cent de la valeur totale de toutes les espèces de poisson débarquées. L'eau de mer réfrigérée est largement utilisée pour la conservation du saumon pendant le transport des terrains de pêche aux usines de conserves et permet d'obtenir même après 14 jours un produit conservé acceptable à partir de saumon en période de jeûne, non éviscéré. Cependant des altérations de la qualité deviennent de plus en plus apparents après sept jours.

On a étudié la possibilité d'éviter l'apparition de changements indésirables en congelant partiellement et en entreposant le poisson dans de l'eau de mer additionnée de sel. Du saumon a été maintenu à −4°C pendant deux semaines sans aucune manifestation de "ventre cuit" ou de détérioration bactérienne. On a pu également empêcher le brunissement de la chair près de la cavité viscérale, causé par la diffusion du pigment à partir du rein, du foie et de la rate.

On a constaté que les lipides du muscle rouge latéral étaient très susceptibles de rancir, mais on a remédié à cet inconvénient en fermant hermétiquement la cuve d'entreposage. La diminution de l'huile libre dans le saumon conservé après congélation partielle a été étudiée.

On a comparé du saumon partiellement congelé avec du poisson non congelé entreposé dans de l'eau de mer réfrigérée. Les changements de poids en cours d'entreposage ont été faibles. Des odeurs de décomposition se sont manifestées en cours d'entreposage dans le poisson non congelé, mais étaient absentes dans le poisson partiellement congelé. L'absorption de sodium et les pertes de potassium étaient du même ordre, mais l'absorption de magnésium était plus faible dans le poisson partiellement congelé.

La congélation partielle du saumon effectuée suivant cette méthode qui n'est pas idéale, mais permet l'entreposage jusqu'à 17 jours. La qualité du produit conservé a été évaluée au moyen d'essais organoleptiques, portant sur la couleur, la formation de grumeaux, la fermeté de la chair, la quantité d'huile libre et l'odeur.

Congelación parcial de salmón del Pacífico destinado al enlatado

En la Columbia Británica el salmón del Pacífico representa el 55 por ciento aproximadamente del valor desembarcado de todas las especies. Se emplea mucho el agua de mar refrigerada para conservar el salmón durante el transporte desde los caladeros a las fábricas de enlatado y esto da un producto enlatado aceptable de salmón no eviscerado, incluso pasados 14 días.

Sin embargo, pasados 7 días, se hacen cada vez más evidentes los cambios perjudiciales de la calidad.

Se ha investigado la posibilidad de evitar cambios inconvenientes congelando parcialmente el pescado y almacenándolo en agua de mar reforzada con sal. Se mantuvo el salmón durante dos semanas a −4°C (25°F) sin que se observaran signos de autolisis en el abdomen. Se evitó que la difusión de pigmentos de riñón, hígado y bazo oscureciera la carne adyacente a la cavidad visceral. Se vió que era muy susceptible al enranciamiento el lípido del músculo lateral rojo pero se corrigió este defecto cerrando herméticamente el depósito de almacenamiento. Se ha investigado la disminución del aceite libre en el salmón enlatado después de la congelación parcial.

Se comparó el salmón parcialmente congelado con el pescado almacenado sin congelar en agua de mar refrigerada. Los cambios de peso registrados durante el almacenamiento fueron pequeños. Surgieron olores debido a la descomposición en el pescado durante el almacenamiento cuando aquél estaba sin congelar, pero no en el pescado parcialmente congelado. La absorción de sodio y las pérdidas de potasio fueron similares, pero la absorción de magnesio fue menor en el pescado parcialmente congelado.

La congelación parcial del salmón hecha de este modo, aunque no es una solución perfecta, facilita un método práctico para el almacenamiento durante un período de hasta 17 días. La calidad del producto enlatado se juzgó a partir de las pruebas organolépticas, incluyendo el color, formación de materia coagulada, firmeza de la carne, cantidad de aceite libre y olor.

IN the British Columbia fishing industry Pacific salmon annually accounts for 55 per cent of the landed value of all species. During the 10-year period from 1955 to 1964 the average landed value of the portion of the total salmon catch utilized for the production of canned salmon was $18 million, representing approximately 45 per cent of the landed value of all species. Sockeye salmon (*Oncorhynchus nerka*), the variety most desired by canners, ranks highest in market value because of its deep orange-red colour, abundant red oil, firm texture and distinctive flavour. In 1966 approximately 40 per cent of the B.C. canned salmon pack was sockeye, having a wholesale value of nearly $23 million. Fishermen received 37 cents per pound (81 cents per kilogram) for whole fish.

During transport of salmon from the fishing grounds to the cannery-refrigerated sea-water (RSW) is now used extensively in place of ice for the preservation of the uneviscerated fish. Laboratory tests indicate that non-feeding salmon yield an acceptable canned product even after 14 days' storage in refrigerated sea-water, but after six or seven days adverse quality changes become increasingly evident in the canned product. Proteolysis of the flesh surrounding the visceral cavity (belly-burn) can

cause serious spoilage. This condition occurs in unevisceratedfish, and when feeding fish are taken and conditions do not permit evisceration before storage, severe proteolysis occurs. Flesh near the visceral cavity becomes soft or even liquefied and a darkening occurs which is apparently the result of the diffusion of pigment from the kidney, liver and spleen. Since the flesh affected by these changes is from the edible part of the fish serious losses occur in scraping away soft and discoloured tissue.

It is apparent that freezing the fish soon after capture should prove useful when the storage period before canning must be longer than that acceptable using ice or refrigerated sea-water. Stansby and Dassow (1951) found in experiments with salmon brine-frozen for later canning, that the fish must be handled, frozen and stored with greater care than is commonly practised in brine-freezing tuna at sea. In canning tuna the fish is pre-cooked and only the light meat is canned while the skin and dark meat are discarded. Salmon is canned with no pre-cook and normally with the skin and the underlying layer of fatty red muscle intact. Thus, rancidity is not a serious problem with canned light meat tuna but any detectable rancid odour of flavour in the lipid of the red lateral muscle results in the downgrading of canning salmon. It is therefore most important that salmon be frozen and stored with an absolute minimum of quality change in the fish if a good canned product is to be produced. Tanikawa, Motohiro and Shoji (1956) have reported that in salmon stored frozen for over 50 days the "cold storage" odour in the canned product is pronounced.

British Columbia salmon "packers" (vessels whose sole function is to transport salmon from the fishing grounds to the cannery) are not equipped for freezing the catch on plates or by air-blast. However, the refrigeration capacity of many of these vessels is sufficient to ensure rapid chilling and only minor alterations would be required to convert them for freezing fish in salt-reinforced refrigerated sea-water. The high rate of heat transfer attainable in brine immersion freezing and the high level of compressor capacity available in the −1° to −4°C (30° to 25°F) temperature range favour the use of this freezing method. The possibility that partial freezing and storage of salmon in reinforced sea-water might provide a practical means of eliminating or reducing belly-burn without being harmful to the quality of the canned product has been investigated. The results of laboratory scale experiments and pilot plant tests indicate that the method should prove useful in the storage of uneviscerated salmon intended for canning when the period of storage must be longer than that acceptable with ice or RSW. This report gives the results of these investigations with sockeye and coho (*O. kisutch*) salmon stored partially frozen at between −4°C and −1°C (25° to 30°F) in sea-water to which salt was added. These fish were compared with unfrozen fish stored in refrigerated sea-water at −1°C (30.5°F).

PROCEDURE

In preliminary work, fish were stored in insulated tanks with loosely fitting lids, but in most of the work reported here tanks were equipped with tightly fitting lids so that they could be completely filled to exclude air. Accurate control of brine temperature is essential. Precise temperature control with a variation of ±0.05 degC (±0.09 degF) has been achieved in laboratory tests by adjusting the salinity to a freezing point just slightly lower than the desired temperature [e.g. for −4°C (25°F), specific gravity = 1.050] and controlling the compressor running time by means of a refrigerant differential pressure contoller. Alternate freezing and thawing of ice on the chiller tubes occurs with each cycle of compressor operation but the brine temperature remains virtually constant since the circulating pump operates continuously. Artificial sea-water for use as the storage solution was prepared according to Lyman and Fleming (1940). Sea-water with NaCl added is referred to as FRSW (fortified RSW).

The occurrence and extent of belly-burn were judged by visual observation, as was reddening of flesh adjacent to the visceral cavity and the kidney. Fish were weighed before and after storage. They were suspended by the gill cover and allowed to drain in air for 1 min before each weighing. Sodium and potassium were measured by flame spectrophotometry and magnesium by colourimetry as previously described by Tomlinson, Geiger and Kay (1965). Oxidative rancidity was detected by odour and taste of raw or cooked muscle. Peroxide value of lipids extracted from the raw flesh was measured by the method of Tarr (1947). Fish were vacuum-packed in cans and processed at 118°C (242°F) for 80 min. Examination of the canned product was conducted by the Fish Inspection Laboratory of the Department of Fisheries, Vancouver, B.C., particular attention being paid to colour, firmness, odour, curd formation and percentage of free oil. Several laboratory experiments were carried out with salmon, in each of which fish stored unfrozen at −1°C (30.5°F) were compared with others stored partially frozen [at −4°, −2.3° or −1.6°C (25°, 27.7° or 28.8°F)]. In one experiment with sockeye, 28 fish were used, in a second 24, while in each of four experiments with coho 24 were used. In each experiment four fish were examined and canned when the experiment was begun, and four from each temperature after storage periods of one and two weeks, and in one experiment with sockeye also after one day.

RESULTS

Belly-burn

Belly-burn occurred irregularly and only mildly in non-feeding sockeye stored at −1°C (30.5°F) for two weeks. In one experiment it was slight but noticeable at −1°C (30.5°F) after one week. At −1.6°C (28.8°F) it was not detected at one week, but was noticeable after two weeks. At −4°C (25°F) it did not occur in two weeks. In non-feeding coho, slight to moderate belly-burn was observed after two weeks at 0°C (32°F), but not after one week; while at −4°C (25°F) it did not occur in two weeks.

In light to heavily-feeding coho, belly-burn was negligible to moderately severe in one week at −1°C (30.5°F) and slight to very severe in two weeks, most of the fish being in the latter condition at that time. At −2.3°C (27.7°F) some belly-burn was found after one and two weeks in fish containing a very large amount of well-digested, unfrozen food, but none was found in

other fish. At −4°C (25°F) belly-burn was not detected in any fish at two weeks. In fish in which belly-burn was not apparent following storage, however, it appeared that the membrane lining the visceral cavity was more easily ruptured during handling than was that of freshly caught fish. The freezing point of several samples of the well-digested food from fish stored at −2.3°C (27.7°F) was investigated and found to be about −4°C (25°F). One sample did not solidify until a temperature of −5.5°C (22°F) was reached.

Reddening of flesh adjacent to the visceral cavity and the kidney

At the higher storage temperature, flesh adjacent to the visceral cavity, particularly that near the liver and kidney, became dark red in colour as storage progressed, seemingly as a result of diffusion of pigment from the organs. This occurred in sockeye in one week at −1°C (30.5°F), in two weeks at −1.6°C (28.8°F), but not at −4°C (25°F). In coho it appeared in some fish in one week at 0°C (32°F) and in all in three weeks. At −1°C (30.5°F) no reddening developed in one week, but in two weeks it was slight in some fish. At −2.3°C (27.7°F) and at −4°C (25°F) no reddening occurred in two weeks. In sockeye held without icing at about 15°C (60°F), reddening became noticeable within 24 h of death.

Weight changes

Weight changes during storage were small and varied from fish to fish. At −1°C (30°F) the average gain in weight at the end of one week was 2 per cent (range 0.2 to 4.6 per cent) and at two weeks 3.5 per cent (2.2 to 4.3 per cent). At −4°, −2.3° and −1.6°C (25°, 27.7° and 28.8°F) the average gain was 1 per cent (0 to 1.4 per cent) at one week and 2.5 per cent (0.7 to 6.0 per cent) at two weeks, no difference between changes at the three temperatures being detected. After one day of storage there was a small loss in weight (<1 per cent) by unfrozen sockeye, whereas in the partially frozen fish there was a small gain (<1 per cent). Coho were not examined for weight changes at one day, since they were held in RSW about two days before being delivered. Consequently, the initial small losses in weight that occur when freshly-caught fish are stored in RSW would have already taken place (Tomlinson, Geiger and Kay, 1965).

Odour of raw fish

After one week of storage at −1°C (30.5°F), no off-odour was detected in either the flesh or the visceral cavity of non-feeding fish, but in heavily feeding fish, although there was no off-odour in the flesh, there was a noticeable putrid odour in the visceral cavity and gut contents of some fish. At two weeks there were putrid odours in the visceral cavities of both lightly and heavily fed fish, and in some of the latter, noticeable unpleasant spoilage odour in the flesh.

At −2.3°C (27.7°F) and −1.6°C (28.8°F), in heavily fed fish only, there was occasional mild off-odour in the visceral cavity and gut contents at the end of one and two weeks storage, but no off-odour in the flesh. At −4°C (25°F) no off-odour was detected after one or two weeks in either visceral cavity or flesh, in fact after two weeks at this temperature gut contents still had an odour like that of freshly-killed fish.

When, in preliminary work, fish were stored partially frozen in tanks open to the air, an unusual, strong, characteristic odour developed within one or two days. This odour seemed to be related to the development of oxidative rancidity in the lipids of the red lateral muscle that also occurred under aerobic conditions, but was unlike the familiar odour of rancid fish oil. The odour has been detected in the early stages of storage of fish in RSW when the storage tank was open to the air, but under these conditions the odour disappeared as storage continued. When air was excluded from the storage tank, neither the odour nor oxidative rancidity developed in partially-frozen fish of initially good quality.

Changes in flesh concentrations of sodium, potassium and magnesium during storage

Changes in muscle concentrations of sodium, potassium and magnesium that took place in the outer 2 cm ($\frac{3}{4}$ in) of the dorsal muscle of sockeye salmon stored either at 0°C (32°F) in RSW or at −4°C (25°F) in FRSW were measured. After two weeks at either temperature, sodium, in the first 0.3 cm ($\frac{1}{8}$ in) of muscle beneath the skin, reached a concentration a little higher than that commonly accepted as most palatable (equivalent to 1 per cent NaCl). In the next 0.3 cm ($\frac{1}{8}$ in) the concentration was a little lower and in the next 1.3 cm ($\frac{1}{2}$ in) was much lower. As a result the average value in the muscle was such that after two weeks the sodium concentration was a little below the most palatable concentration at these and at the other temperatures investigated, although it exceeded that concentration in some fish. The increase in sodium concentration was a little greater in the partially-frozen fish than it was in those stored at −1°C (30.5°F) after two weeks, but at −4°C (25°4F) it was a little lower than at 0°C (32°F). It thus appears that the lowering of the storage temperature largely overcomes the effect of the necessary increase in the sodium concentration of the storage solution insofar as sodium penetration into the fish is concerned. Losses of potassium were a little smaller from the partially-frozen than from the unfrozen fish. Changes in magnesium concentration were small in comparison with those of sodium and potassium. These changes were much smaller at −4°C (25°F) than at 0°C (32°F), but were of sufficient magnitude to be of possible significance in retarding development of toughness (Buttkus and Tarr, 1962).

Occurrence of oxidative rancidity under aerobic storage conditions

In preliminary experiments, when either sockeye or coho salmon, canned after storage for one or two weeks at −4°C (25°F) in tanks open to air, were examined within one month of being canned, distinctly rancid odour and flavour were found, particularly in the red lateral muscle. The defect was most pronounced in fish canned after two weeks storage. When other samples from the same fish were examined three months after being canned, the rancid odour and flavour were not detected in fish canned after one week of storage, but were very strong in those canned after two weeks. In fish canned after storage for two weeks in RSW at 0°C (32°F) under similar aerobic conditions, slight rancidity was occasion-

ally detected in the red lateral muscle. In subsequent work storage tanks were filled with solution and sealed during the storage period and no further trouble with development of rancidity was experienced in fish of initially good quality.

Canned product

There was little to choose between fish canned after being stored partially frozen and those stored unfrozen, such differences as occurred usually but not always tending to favour the partially-frozen fish.

Darkening of flesh adjacent to the visceral cavity was delayed or eliminated in the partially-frozen fish, and these fish did not soften during storage as did the unfrozen fish. The degree of darkening in fish stored in RSW was somewhat variable from experiment to experiment. The data of one experiment showed a delay in development of darkening at −1.6°C (28.8°F), but in other experiments little darkening was observed in any of the fish. However, in two other experiments with coho very noticeable darkening occurred in RSW (0°C, 32°F), whereas none was observed at −4°C (25°F).

Storage by either procedure had some effect on the flavour and odour of the subsequently canned product. With fish of good initial quality, these changes seemed to involve some loss of the initial sweet, fresh flavour rather than a development of new flavour or off-odour, but in fish of inferior initial quality there was a tendency for some deterioration of odour to occur. Odours present in the raw flesh were obviously diminished during canning.

Although the data from individual experiments provided no consistent evidence for a serious influence by either method of storage on the colour of the flesh or on the quantity of curd formed during canning, there appeared to be a tendency for RSW-stored fish to have a little better colour than the FRSW-stored fish and for the latter, overall, to have a little more curd (12.5 per cent of the cans of RSW fish showing curd in comparison to 15 per cent of the FRSW fish). There also appeared to be an overall tendency to an increase in curd as a result of storage by either method, 8.33 per cent of the control cans showing curd in comparison with a combined average of 13.75 per cent for the cans from stored fish. Schmidt and Idler (1958) earlier reported that the colour of canned sockeye was not adversely affected by storage of the raw fish in RSW (−1°C, 30°F), but these investigators (1955) did observe an increase in curd in both coho and sockeye salmon during storage in RSW.

During storage by either procedure, there was a distinct decrease in the quantity of free oil found in the subsequently canned product. The matter has been investigated further by Bilinski *et al.* (1966, 1967) with the result that the apparent decrease in free oil that occurred in salmon canned after storage in RFSW has been shown to be real. It has also been shown that there is no corresponding decrease in the total lipid content of the canned product. However, it has been found that a decrease in free oil of about the same magnitude occurs in iced fish or in fish stored in RSW, but more slowly. After centrifugation (approximately 600 g, 60 min) of intact cans the drained free oil content of cans having a low content when measured without prior centrifugation was equal to that of cans of high drained free oil content. It is suggested that oil binding in canned salmon is physical rather than chemical and might be related to protein denaturation during cold storage, resulting in formation of a more fibrous texture, less favourable for the release of oil from the tissue during canning.

CONCLUSIONS

The following information derived from pilot-scale experiments should be considered in assessing the suitability of this method for industrial application.

(1) Most of the proven advantages of RSW storage of cannery salmon are retained. These include rapid chilling, reduction in shrinkage losses from pressure in storage, and the convenience of bulk storage.

(2) Sodium concentration in the canned product can be maintained at an acceptable level if care is taken to maintain the minimum salinity in the storage solution. In a recent experiment sockeye were stored in FRSW at −4°C (25°F) for 17 days. The average total chloride in the product canned without added salt was found to be less than half the concentration found in commercial packs.

(3) Excessive buoyancy of the mass of partially-frozen fish is not a serious problem. This can be attributed to the use of dilute brine solutions which have a lower density than raw fish, and the limited formation of ice in the flesh, since even at −4°C (25°F) only about 65 per cent of the water in the flesh is converted to ice.

(4) Constant immersion of the stored fish prevents surface desiccation and provides protection from oxidation if air is eliminated from the storage system. Dry storage of partially-frozen salmon under nitrogen would be difficult to apply commercially.

(5) The fish can be thawed before unloading since further storage of the fish ashore is not necessary, as ample cannery capacity is available to provide for immediate processing.

(6) In a recent test a 700 kg (1,500 lb) lot of sockeye was stored for 17 days at −4°C (25°F) before canning. This lot was passed grade "A" by the Inspection Laboratory.

(7) Salted salmon roe or "caviar" is considered a delicacy in Japan. Canadian production and export of salmon roe to Japan has increased rapidly during the last two to three years totalling 300 t in 1966. Freezing of the roe before processing may cause undesirable changes, but this has not yet been studied here and the possible economic effects are not known.

References

BILINSKI, E, LANG, G and TOMLINSON, N Evidence for the
1966 binding of oil in salmon canned after storage in ice or in a partially frozen condition. *J. Fish. Res. Bd Can.*, **23**, 917–919.

BILINSKI, E and CLEMENT, P The binding of oil in canned
1967 salmon. *Ibid.* (In press.)

BUTTKUS, H and TARR, H L A Physical and chemical changes
1962 in fish muscle during cold storage. *Fd Technol., Champaign*, **16**, 84–88.

LYMAN, J and FLEMING, R H Composition of sea water.
1940 *J. mar. Res.* **3**, 134–146.

SCHMIDT, P J and IDLER, D R Transport and storage of fish in
1955 refrigerated sea water. III. Curd in canned salmon as related to *post mortem* age of fish. *Prog. Rep. Pacif. Cst Stns*, No. 104, 9–10.

SCHMIDT, P J and IDLER, D R Predicting the color of canned
1958 sockeye salmon from the color of the raw flesh. *Fd Technol., Champaign*, **12**, 44–48.

STANSBY, M E and DASSOW, J Use of frozen salmon for
1951 canning. *Comml Fish. Rev.*, **13**(4), 20–25.

TANIKAWA, E, MOTOHIRO, T and SHOJI, S Studies on the
1956 manufacture of canned salmon (1–4). *Bull. Fac. Fish. Hokkaido Univ.*, **6**(4), 317–340.

TARR, H L A Control of rancidity in fish flesh. I. Chemical
1947 antioxidants. *J. Fish. Res. Bd Can.*, **7**, 137–154.

TOMLINSON, N, GEIGER, S E and KAY, W W Sodium, potas-
1965 sium and magnesium concentration and weight changes in fish stored in refrigerated sea water in relation to biochemical changes associated with *rigor mortis*. *J. Fd Sci.*, **30**, 126–134.

Anomalous Behaviour of Frozen Cod Muscle Stored Near its Melting Point

by R. M. Love

Anomalous behaviour of frozen cod muscle stored near its melting point

The muscle of cod frozen in a conventional air-blast freezer at low temperatures rapidly becomes tough to eat if subsequently stored near its melting point. However, if the fresh material is frozen at the same high storage temperature, it deteriorates more slowly. Earlier studies with the cell fragility technique showed that the difference was real, being governed solely by the temperature at which the fish was originally frozen.

Since the fish frozen at −30°C (−22°F) and warmed up to −1.5°C (29.3°F) probably contains more ice than fish frozen at −3°C (26.6°F) then warmed to −1.5°C (29.3°F), it is likely that the tissue salts in the former case are concentrated to a greater extent than in the latter.

The structural proteins of the muscle, actin and myosin, aggregation of which is thought to relate to the toughening perceived on eating, will dissolve in salts of a certain strength, but are almost insoluble in either smaller or greater concentrations. Evidence is presented in this paper to show that in "superchilling", where the fish is just frozen at about −2°C (28.4°F) and never drops below this temperature, the tissue salts become concentrated to that particular strength which favours the extraction of the structural proteins. With such proteins partially dissolved, the aggregation, and hence the toughness, occurs only to a limited extent, so that the usual temperature/time relationship governing the development of toughness in frozen fish muscle does not apply.

Comportement anormal du muscle de morue congelée entreposée à une température proche de son point de fusion

Du muscle de morue congelée à basse température dans un congélateur conventionnel à circulation forcée devient rapidement coriace s'il est ensuite entreposé à une température proche de son point de fusion. Cependant si le produit frais est congelé à une température aussi élevée que celle d'entreposage, il se détériore plus lentement. Des études précédentes effectuées en utilisant la technique de la fragilité cellulaire avaient mis en lumière une différence réelle, influencée uniquement par la température à laquelle le poisson avait été initialement congelé.

Du moment que le poisson congelé à −30°C et chauffé jusqu'à −1,5°C contient probablement plus de glace que le poisson congelé à −3°C et chauffé jusqu'à −1,5°C, il est vraisemblable que la concentration des sels dans les tissus est plus élevée dans le premier cas.

Les protéines structurales du muscle, à savoir l'actine et la myosine, dont l'agrégation est mise en relation avec le durcissement relevé à la consommation, seront dissoutes dans les sels à un certain taux de concentration, mais sont presque insolubles dans les concentrations plus faibles ou plus élevées. Le présent document montre que pendant l'entreposage frigorifique à basse température, au cours duquel le poisson est congelé à −2°C seulement et ne descend jamais au-dessous de cette température, les sels atteignent dans les tissus la concentration qui facilite l'extraction des protéines structurales. Ces protéines étant partiellement dissoutes, l'agrégation —et par conséquent la coriacité—ne se manifeste que dans une faible mesure, si bien que la corrélation courante température/temps qui provoque l'apparition de la coriacité dans le muscle de poisson congelé, n'est pas applicable dans ce cas.

Comportamiento anómalo de la carne de bacalao congelada y almacenada cerca de su punto de fusión

La carne de bacalao congelada por circulación forzada de aire a bajas temperaturas rápidamente se pone demasiado dura para poder comerla si a continuación se almacena cerca de su punto de fusión. Sin embargo, si el material fresco se congela a la misma elevada temperatura del almacenamiento, se deteriora con más lentitud. Los estudios anteriores realizados con la técnica de desintegración de las células mostraron que la diferencia era real, dependiendo solamente de la temperatura a la que se congeló originalmente el pescado.

Puesto que el pescado congelado a −30°C y calentado después a −1,5°C probablemente contiene más hielo que el pescado congelado a −3°C y calentado luego a −1,5°C, es probable que, en el primer caso, las sales de los tejidos se concentren en mayor medida que en el último.

Las proteínas estructurales de la carne, actina y miosina, cuya agregación se cree que está relacionada con el endurecimiento que se nota al comerla, se disolverán en sales de una cierta concentración, pero son casi insolubles en concentraciones más bajas o más altas. En este estudio se presentan pruebas para demostrar que en el sobreenfriado, cuando el pescado se congela alrededor de los −2°C y no baja nunca por debajo de esta temperatura, las sales de los tejidos se concentran en el grado que favorece la extracción de las proteínas estructurales. Con tales proteínas parcialmente disueltas, la agregación de ellas, y por tanto la consistencia de la carne, sólo se produce en una medida limitada, de modo que no es aplicable la relación usual temperatura/tiempo que rige el desarrollo de la dureza en la carne del pescado congelado.

WHEN fish are kept in the frozen state, the muscle proteins gradually alter in character and, since the texture becomes tougher and more fibrous, they become less desirable as articles of food. Using cod (*Gadus morhua* L.) frozen at −29°C (−20°F) and held at temperatures between −4°C (24.8°F) and −29°C (−20°F) inclusive, Love (1962) showed that the log of the rate of reaction was proportional to the temperature of storage, whether the change in the proteins was measured by protein extractability in 5 per cent sodium chloride (Dyer, French and Snow, 1950) or by the cell fragility technique (Love and Mackay, 1962). Further work with the cell fragility technique showed that the rate of reaction continued to rise until −1.5°C (29.3°F), above which it dropped owing to the melting of much of the ice (Love and Elerian, 1964).

Since the deterioration of cod under these conditions was extremely rapid, it was surprising to learn that fish landed in Portugal after storage on a catching vessel at temperatures just below their freezing point ("superchilled") were of good quality (Scarlatti, 1964). Further investigation (Love, 1966) showed that the factor causing the anomaly was the temperature at which the fish were originally frozen: in the earlier work all the fish had been air-blast frozen at −29°C (−20°F) before being warmed up to the various other temperatures, while in Scarlatti's process the fish were cooled to just 1°C or 2°C below freezing point.

The purpose of the present paper is to describe a more detailed investigation of the phenomena occurring at a storage temperature of −1.6°C (29°F).

Extension of the use of the cell fragility method

In the original form of this technique (Love and Mackay, 1962), a sample of fish in dilute formaldehyde solution was subjected to accurately-controlled homogenization in a special blender. In fresh fish, the cells were separated from each other and then further degraded to myofibrils: the homogenate was correspondingly cloudy and showed a high optical density in a colorimeter. Cold storage caused the myofibrils to develop an increased coherence, so that progressively larger associations appeared in the homogenates until in very tough specimens the homogenates consisted of intact cells only, suspended in a clear liquid. The optical density thus diminished according to the time of frozen storage, and a useful method for investigating frozen fish muscle had been evolved.

After many investigations of this type, it was noticed that the optical density could diminish in unfrozen fish which were becoming soft for some reason, e.g. starvation (Love and Mackay, 1962), advanced bacterial spoilage (Love *et al.*, 1965), high pH—perhaps another manifestation of starvation (Kelly *et al.*, 1966), and after treatment with sodium polyphosphate solution (Love and Abel, 1966). Photomicrographs showed that in each instance the myofibrils were being chopped into much shorter lengths by the homogenization, breaking at the Z-line, and also were becoming more transparent and showing less contrast under the microscope. It was concluded that structural protein was being removed from the myofibrils in every case where a softening of the tissue gave rise to a homogenate of lower optical density (Love, 1967).

MATERIAL AND METHODS

Cod (*Gadus morhua* L.) caught by trawl-net within 30 miles of Aberdeen were used. Protein extractability and dissection of samples were carried out as described by Ironside and Love (1958), and cell fragility determinations as by Love and Mackay (1962). Material for photography was as fresh as possible, usually being photographed within 10 min of homogenizing, since myofibrils tended to clump together later. Light-photomicrographs were made under phase contrast, and electron photomicrograph preparations were shadowed with Au/Pd on a formvar support.

Each sample for determination consisted of 10 pieces of muscle, each from a different fish, so that the effects of biological variation were reduced. Freezing at −29°C (−20°F) was carried out for 3 h in an air-blast freezer, while freezing at the high temperature was done by placing samples, vacuum-packed in polythene bags, in a bath of sodium chloride solution at −3°C (26.6°F) until they all contained some ice, and then transferring them to a cabinet at −1.6°C (29°F) as described by Love and Elerian (1964).

RESULTS

Optical photomicrography of homogenates

Taking the results of the optical microscope first, it was found (fig 1) that there was a big difference between the homogenates just one day after freezing, both samples having been kept at −1.6°C (29°F) for some hours before thawing at room temperature. The myofibrils are long in picture A (low temperature freezing) and one or two can be seen to be still joined together along their lengths. Picture B (freezing at −1.6°C, 29°F) shows almost no evidence of such aggregation, many of the myofibrils are shorter, and the picture is less distinct than A, though the striations of the fibrils are still visible.

After one week at −1.6°C (29°F), very striking changes occurred. In picture C, larger bundles of myofibrils have formed, as is usual in cold storage at lower temperatures, but it is noteworthy that some of the unaggregated myofibrils are now shorter in length. The corresponding sample which had been frozen at the high temperature, picture D, presents a remarkable appearance: virtually no side-to-side aggregation has yet occurred, but the indistinct-looking myofibrils have become so weakened that they have broken into minute lengths.

The appearance after two weeks was intermediate between one and three weeks (not illustrated).

After three weeks at −1.6°C (29°F) the myofibrils in the control sample frozen at −29°C (−20°F) formed for the most part aggregates which were too big to be photographed at this magnification; a portion of one is shown in picture E. The few unaggregated myofibrils are shorter still. With the unaided eye it could be seen that the large aggregates, usually of the diameter of intact cells, were much shorter than those normally occurring after storage at, say, −14°C (7°F), so the Z-line is evidently weakened even if aggregation occurs. No further aggregation had taken place in the samples frozen at the high temperature (picture F), and by now the cross-striations were indistinct.

After four weeks the situation was essentially the same (not illustrated).

Electron photomicrography of homogenates

Turning now to higher magnifications (fig 2), it can be seen that one day after freezing there is not much difference between the myofibrils from the two initial freezing temperatures (pictures A and B), but those from the higher temperature are paler, some material having presumably been removed from them. Breakage clearly occurs at the Z-line.

After two weeks at −1.6°C (29°F), however, big changes are apparent. Both groups of fibrils are paler (pictures C and D), much of the protein forming the dark striations having been removed. Fibrils from the "superchilled" fish (D) are paler than those frozen at the lower temperature, and are chopped into extremely short lengths. An interesting feature of picture C is that several fibrils are joined from side to side, but at the same time they have been chopped into a very short length. Most of the material from the controls is at this stage aggregated into masses far too large to photograph at such a high magnification, so the fibrils illustrated in both pictures C and E are in a sense unrepresentative. The situation after three weeks was similar, so is not illustrated.

After four weeks, the control fibrils (E) were paler still. At this point, spoilage bacteria appeared in both groups, and some can be seen in each picture. Storage was discontinued beyond four weeks.

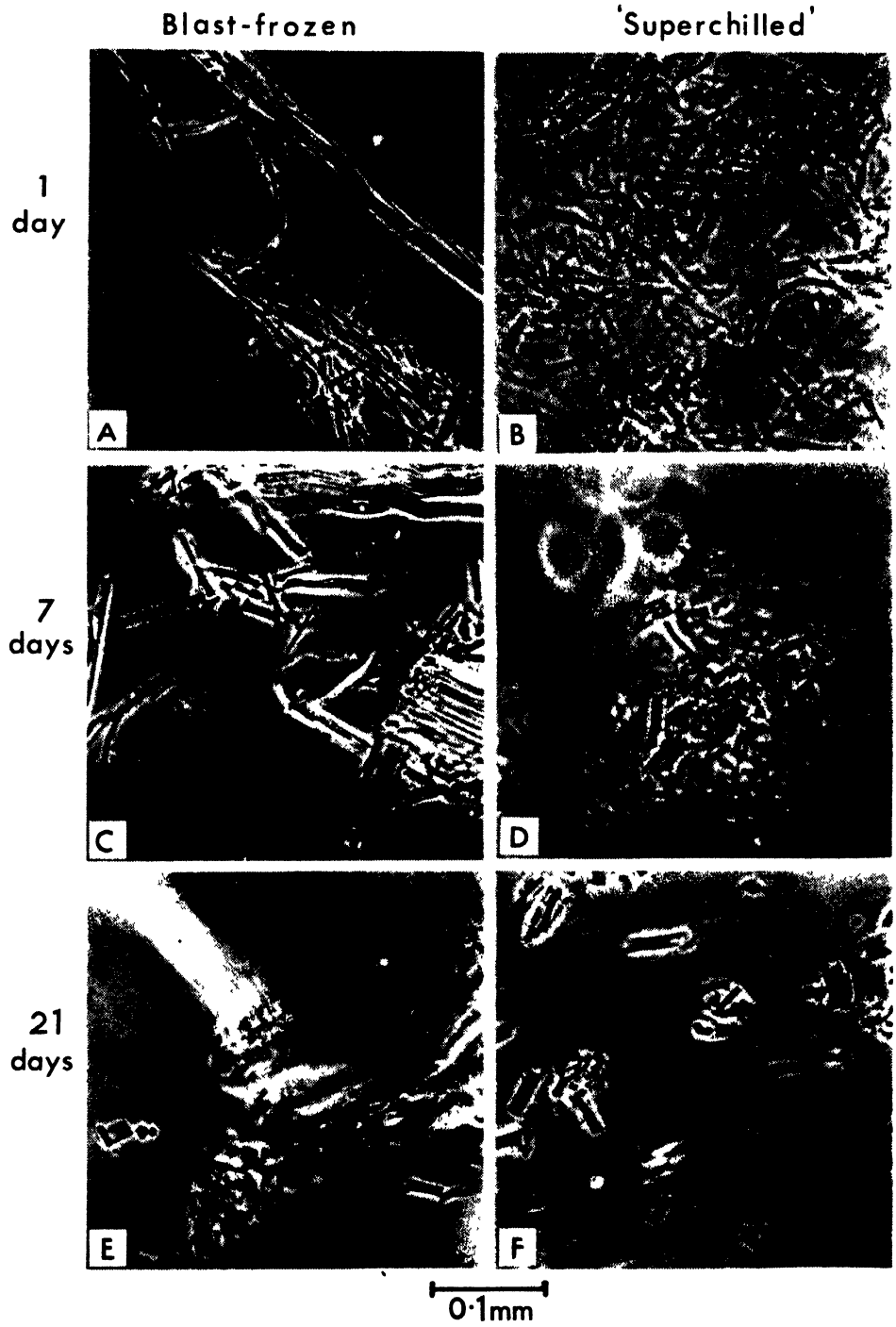


Fig 1. Optical microscope pictures of homogenates of cod muscle, either after freezing in an air-blast at −29°C (−20°F) or in a bath at −1.6°C (29°F), both groups being stored together at −1.6°C (29°F) afterwards. Storage times are shown on the left-hand side

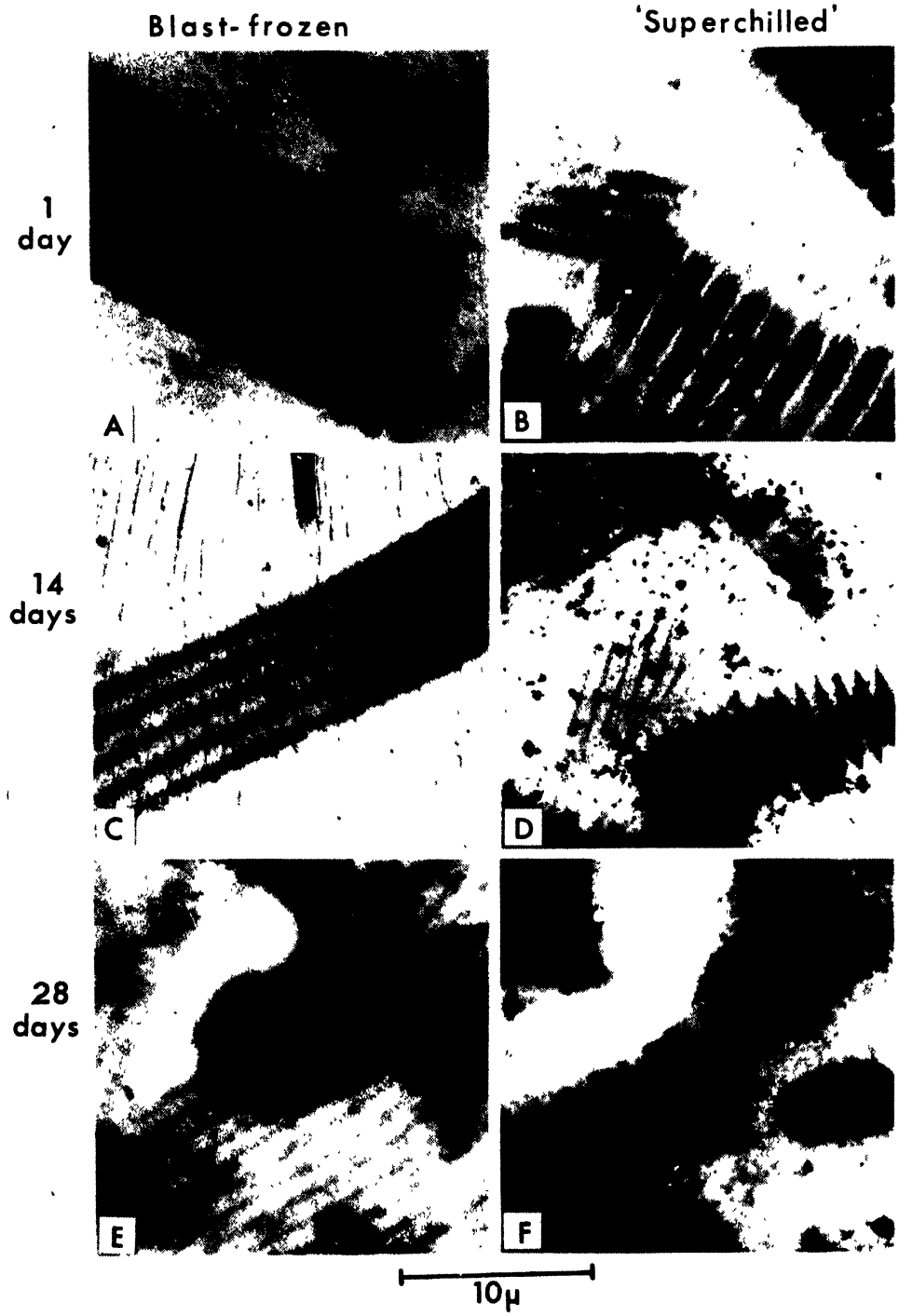


Fig 2. Pictures of homogenates taken with electron microscope. Other data as in fig 1

Measuring extractability of the muscle proteins

The photomicrographs showed that "superchilling" caused some of the structural proteins to disintegrate. The purpose of the following experiment was to attempt to discover whether they had been dissolved by enzymic degradation or by simple solution in the concentrated tissue salt.

Muscle samples were homogenized in sodium chloride solutions of concentrations ranging from 1 to 5 per cent inclusive, and the extractability of the protein nitrogen was measured at weekly intervals on the samples, frozen at each temperature and stored at −1.6°C (29°F).

The results using 3, 4 and 5 per cent NaCl were almost identical, so only those in 3 per cent are illustrated in fig 3, along with those homogenized in 1 and 2 per cent salt.

Fig 3 shows that on the day immediately after freezing there was a small difference in the extractability with 3 per cent NaCl according to the initial freezing temperature. Although the difference was small in either 3,

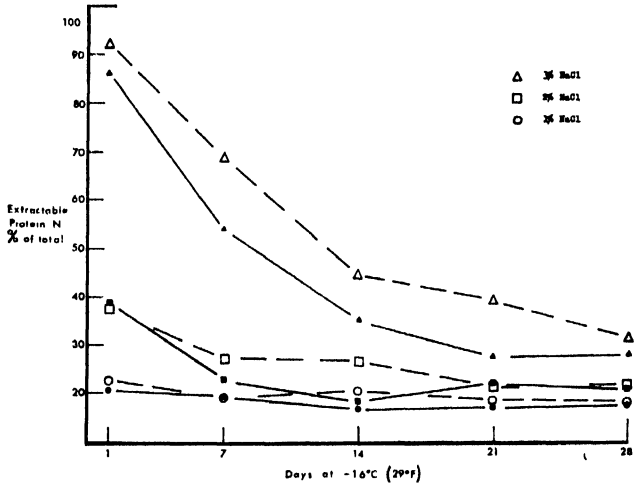


Fig 3. Extractability of protein nitrogen in "superchilled" and control cod, during storage. Hollow symbols represent "superchilled" samples, solid symbols the controls frozen at −29°C (−20°F)

4 or 5 per cent NaCl, it was noticeable that the material frozen at the lower temperature was invariably the less extractable. While this may have been a lesser manifestation of the phenomenon seen in the remainder of the curves, this difference may also have been partly the result of damage to the protein caused by the freezing out of more "bound" water at −29°C (−20°F) than at −1.6°C (29°F). Such a phenomenon has already been observed and described in detail (Love and Elerian, 1963).

A week later, when some deterioration had occurred, the difference was more than twice as great, "superchilled" samples yielding much more protein to the extracting medium, the enhanced extractability of the superchilled samples corresponding with the great breakup of myofibrils seen in fig 2D. This difference was maintained for the following two weeks, and then diminished as the asymptote was approached. Much less protein was dissolved by 2 per cent sodium chloride, and the differences between the curves were correspondingly smaller, but the effect was perceptible. One per cent sodium chloride dissolved little protein, and the differences resulting from the two freezing temperatures were insignificant.

pH of the muscle samples

The pH values of homogenates of the two groups of fish muscle are shown in fig 4, 10 g muscle being homogenized with 20 ml water in each case (averages of two determinations).

With one exception, the pH values of the "superchilled" samples were high, while those of the samples frozen at the lower temperature started low and increased during storage at −1.6°C (29°F). When four members of

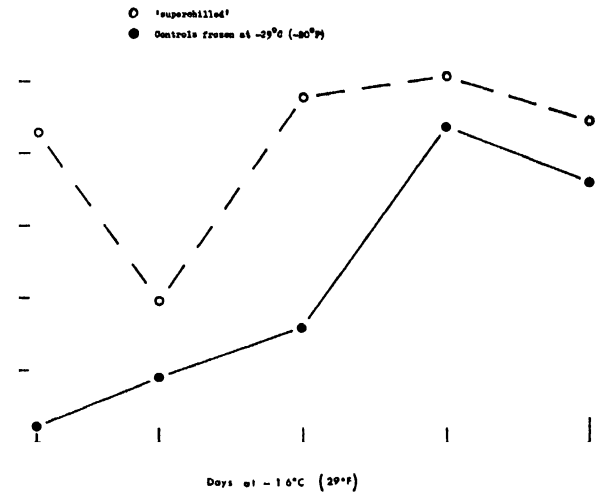


Fig 4. The pH of cod muscle during storage for various times

the laboratory staff tasted steam-cooked samples on two occasions, they found that the "superchilled" samples were less tough than the controls when tasted after three weeks at −1.6°C (29°F) but that the samples could not be distinguished when tasted the day after freezing. The significance of this will be discussed later.

SUMMARY

The question now to be resolved is this: does the tenderness of "superchilled" fish result from enzymic breakdown of the structural proteins, or from the action of the tissue salts which, concentrated by ice formation, could conceivably act as a protein solvent?

Love and Ironside (1958) showed that when cod muscle denatured and became tough during cold storage at lower temperatures, the extractability of the actomyosin nitrogen in 5 per cent NaCl fell to an asymptotic value close to 30 per cent of the total protein nitrogen. The present control (low temperature freezing) curve with 3 per cent NaCl (fig 3) confirms this. If the actomyosin molecules were split by enzyme action into smaller fragments, we would expect this "limit" extractability value to rise in the "superchilled" samples, since the fragments would dissolve more readily. In the same way, we would expect the extractability of "superchilled" protein in 1 per cent NaCl to be much greater than in the controls. In fact neither of these possibilities occurs: the asymptotic value

of the extractability of "superchilled" samples in 3 per cent NaCl after storage will clearly (fig 3) soon merge with that of the control, while the extractabilities in 2 and 1 per cent NaCl differ little between the two temperature groups and in fact are, one day after freezing, close to the values reported by Dyer, French and Snow (1950) for unfrozen cod muscle.

These findings probably rule out enzyme activity, which would have needed to be fairly extensive to produce results like those in fig 1D.

On the other hand, a mechanism for the tissue's own mineral substances acting as a solvent and removing structural material as shown, for example, in fig 2D, is quite feasible.

Dyer, French and Snow (1950) showed that 3 to 6 per cent NaCl inclusive, extracted the largest proportion of cod actomyosin, the extractability diminishing with higher or lower concentrations. Now the quantity of ice present in "superchilled" fish is less than that in fish frozen by the usual procedures to low temperatures and then warmed up (Love and Elerian, 1963), so the tissue salts will have a lower concentration which now appears to fall within this "critical" range.

Fig 1 shows that the removal of structural material, which causes the weakened fibrils to break at the Z-line, is not complete the day after freezing, but probably is so after a week. Fibrils from which the structural material has been removed do not aggregate, so the material never becomes tough (Love, 1967). One might suggest that it would not toughen however long it was stored at −1.6°C (29°F), since bacterial autolysis would play an increasing part with the passage of time. It is hoped to investigate this experimentally.

Some solvent action clearly goes on in the samples frozen at −29°C (−20°F), since although most of the myofibrils do aggregate from side to side, the Z-line is weakened and the aggregates are chopped into short lengths. Any unaggregated fibrils resemble those of "superchilled" muscle (figs 1E and 2E), being depleted and short.

The conclusion to be drawn from figs 1 to 3 therefore is that "superchilling" causes some of the structural proteins to be dissolved out of the muscle fibrils, probably by the tissue salts reaching a critical concentration range through the formation of the ice. Proteins dissolved in this way evidently aggregate more slowly during storage and so remain extractable by sodium chloride solution for a longer time. Myofibrils depleted by the process do not bind together from side to side as in fish muscle stored at lower temperatures, so the product does not toughen.

If we regard "superchilled" samples as containing much dissolved protein all through the experiment and the controls as containing progressively more dissolved material (figs 2A, 2C and 2E), there appears to be a relationship between the amount of protein in solution and the pH.

The results of the limited tasting test are interesting in this context, since no difference was detected between the textures of the control and "superchilled" samples immediately after freezing, where there was more than 0.4 pH unit difference between them. In contrast, a clear difference was found by the tasters after three weeks at −1.6°C (29°F) where there was less than 0.1pH unit difference. Differences in extractability (fig 3) seem to follow the results of tasting more closely.

In a recent paper describing frozen cod stored at low temperatures, Cowie and Little (1966) found that the pH of the muscle was a "much better" guide to the toughness of the cooked muscle as tasted than was protein extractability in sodium chloride. The present results appear to show that the reverse is true under certain circumstances.

Acknowledgments

The work described in this paper was part of the program of the Ministry of Technology. Much of the experimental work was carried out by Mr. John Smith.

References

COWIE, W P and LITTLE, W T *J. Fd Technol.*, **1**, 335. 1966

DYER, W J, FRENCH, H V and SNOW, J M *J. Fish. Res. Bd Can.*, 1950 **7**, 585.

IRONSIDE, J I M and LOVE, R M *J. Sci. Fd Agric.*, **9**, 597. 1958

KELLY, K, JONES, N R, LOVE, R M and OLLEY, J *J. Fd* 1966 *Technol.*, **1**, 9.

LOVE, R M *J. Sci. Fd Agric.*, **13**, 269. 1962

LOVE, R M *Nature, Lond.*, **211**, 981. 1966

LOVE, R M Rheology and texture of foodstuffs. Symposium 1967 sponsored by the Society of Chemical Industry and the British Society of Rheology, 5th–6th January 1967, London. (In press.)

LOVE, R M and ABEL, G *J. Fd Technol.*, **1**, 323. 1966

LOVE, R M and ELERIAN, M K *C.R. XI Congr. int. Froid*, 1963 p. 887.

LOVE, R M and ELERIAN, M K *J. Sci. Fd Agric.*, **15**, 805. 1964

LOVE, R M and IRONSIDE, J I M *Ibid.*, **9**, 604. 1958

LOVE, R M and MACKAY, E M *Ibid.*, **13**, 200. 1962

LOVE, R M, AREF, M M, ELERIAN, M K, IRONSIDE, J I M, 1965 MACKAY, E M and VARELA, M G. *Ibid.*, **16**, 259.

SCARLATTI, E *Revue gén. Froid*, **55**, 863. 1964

DISCUSSION

Carlson, Peters and Lane (U.S.A.)—presented by Holston (U.S.A.): Work on the superchilled storage of haddock (*Gadus aeglefinus*) was started at the U.S. Bureau of Commercial Fisheries Technological Laboratory, Gloucester, Massachusetts, a short time after we received the news of Scarlatti's report at the 1964 OECD Scheveningen meeting. At that meeting, Scarlatti (1965) described the system used aboard

certain Portuguese fishing vessels in which temperatures from −1° to −3°C (30.2° to 26.6°F) were used to hold iced fish, successfully, for 30 days and longer.

In our work we have investigated the superchilled storage of haddock, (a) in ice at temperatures from −1° to −3°C (30.2° to 26.6°F), and (b) in circulating air at individual temperatures within ±0.5° of −1°C (30°F), −2°C (28°F) and −3°C (26°F). In brief, our findings on superchilled storage have been similar to the findings of other investigators (Merritt, 1965; Partmann, 1965; Power and Morton, 1965). Haddock stored in ice at superchilled temperatures cooled slowly below 0°C (32°F) and froze into a mass that was very difficult to handle. The appearance of the raw fillets from the superchilled haddock was poor—soft texture, watery, broken tissue, and yellow off-colour. Despite these poor quality factors, the laboratory taste panel judged that steam-cooked fillets from haddock stored at −2°C (28°F) and −3°C (26°F) were of edible quality for the 28 days that the tests were conducted. Fillets from haddock, stored at −1°C (30°F) were judged to be edible for about 21 days.

In our investigations, we also have been concerned about the storage life of frozen packaged fillets prepared from superchilled haddock. It is this phase of our investigation that will be reported in greater detail here.

Three experiments were conducted in which very fresh eviscerated haddock were stored at −2°C (28°F) for periods up to four weeks. Fish flesh temperatures were monitored with thermocouples. At storage intervals of two, three and four weeks, samples of the superchilled haddock were removed from storage and the partially frozen fish were thawed, filleted and packaged in 0.45 kg (1 lb) self-locking waxed cartons. The cartons of fillets then were plate frozen at −28.9°C (−20°F) and were stored at −17.8°C (0°F) or at −23.3°C (−10°F). Quality evaluations of the fillets were made by the laboratory taste panel just prior to freezing and at intervals following frozen storage. More complete details on the superchilling phase of each of the three superchill-freezing tests are given in the following paragraphs.

In the first test, eviscerated haddock were stored on wire-mesh trays in a superchilled storage box. The fish were cooled to −2°C (28°F) and stored at that temperature in circulating refrigerated air. The fish were positioned in the storage box so that refrigerated air could contact the bottom and top surfaces of each fish.

In the second test, eviscerated haddock initially were cooled rapidly to −2°C (28°F) by immersion for 6 h in a refrigerated 50 per cent propylene glycol solution. The cooled fish then were placed on wire-mesh trays in a superchilled storage box and were stored at −2°C (28°F) in circulating refrigerated air.

A major objective of the third test was to determine if rapid cooling, to superchilled flesh temperatures, would have an improved effect on the texture of recovered fillets and, possibly, on subsequent frozen storage life.

About 318 kg (700 lb) of very fresh eviscerated scrod haddock were divided into four equal portions. One portion was pre-cooled to −1.7° to −2°C (29° to 28°F) by immersion for 9 h in a refrigerated 7 per cent brine solution held at about −2.5°C (27.5°F). The pre-cooled fish then were placed in a storage box in circulating refrigerated air at −2°C (28°F). A second portion was pre-cooled to −1° to −2°C (30° to 28°F) by immersion for 7 h in a R12 to R114 mixture having a boiling point of −2°C (28°F). These pre-cooled haddock also were placed in a storage box in circulating refrigerated air at −2°C (28°F). The third portion was loaded directly into a storage box for cooling and subsequent superchilled storage in circulating refrigerated air at −2°C (28°F). The fourth portion of the haddock was packed in ice for use as control samples.

For the three portions of superchilled haddock, two methods of storage were used in each of the boxes. In one half of the space, in each box, about 45 kg (100 lb) were bulk stored in two nylon mesh bags. In the second half of the box space, the remaining 45 kg (100 lb) of haddock, for each portion, were placed on spaced wire-mesh trays. Thus −2°C (28°F) refrigerated air circulation was expected to be poor through the bulk stored haddock and good through the haddock on the trays.

In the first test, temperature measurements, with thermocouples in the haddock flesh, showed that all of the superchilled air cooled and stored fish reached −2°C (28°F) flesh temperatures in five to seven days. Thus the rate of chilling was very slow. On visual examination, the raw fillets, prior to freezing, showed the same rough watery appearance noted in early superchilled tests. After two, three and four weeks of superchilled storage at −2°C (28°F), steam-cooked samples of the haddock were evaluated by the laboratory taste panel. On the basis of a nine-point quality scale, the samples were judged to be good (7) to fair (6) in quality, prior to freezing.

After frozen storage at −17.8°C (0°F) the haddock fillets were evaluated again by the laboratory taste panel. Samples which had been subjected to a combination of two weeks of superchilled storage and 48 days of frozen storage were unmarketable. The same judgment was made for the third and fourth week superchilled samples after 40 and 30 days of frozen storage respectively.

In the second superchill-freezing test, propylene glycol penetration into the fish was so excessive that the fillets were badly off-flavoured and the test was terminated. In the raw state, the fillets from the haddock cooled in propylene glycol had a much firmer and smoother appearance than the rough appearing fillets recovered from either air-cooled or iced superchilled haddock.

In the third test, a record of the flesh temperatures for the haddock pre-cooled in brine and in the R12 to R114 mixture, showed that the temperatures remained at close to −2°C (28°F) throughout the four weeks of superchilled storage. The air-cooled, shelf-stored haddock showed flesh temperatures of −2°C (28°F) after three to seven days of storage. The air-cooled bulk stored haddock became chilled on the outer perimeter of the mass, but not toward the centre. These fish showed a temperature range from 3° to −1°C (37° to 30°F) and were discarded after two weeks of storage.

Visual examination of the raw fillets from these superchilled fish indicated that the refrigerant-cooled and brine-cooled haddock yielded fillets that were slightly better in appearance on the cut surface than the fillets from air-cooled haddock. However, all of the fillets were much rougher appearing than fillets from iced haddock. In addition, fillets from the brine-cooled haddock showed areas of yellow discolouration.

Prior to freezing, the laboratory taste panel judged that the quality of the fillets was fair (6), after storage at −2°C (28°F) for two, three and four weeks. After four weeks of storage at 23.3°C (−10°F), all of the fillets were examined by the taste panel. Two samples were determined to be marketable. These were (1) fillets prepared from haddock which had been air cooled and shelf stored for two weeks at −2°C (28°F), and (2) fillets prepared from refrigerant-cooled, shelf-stored haddock, stored at −2°C (28°F) for two weeks. After eight weeks of storage at −23.3°C (−10°F), these two samples were judged to be unmarketable. Thus the frozen storage life at −23.3°C (−10°F) for these two samples was between four and eight weeks.

The results of our three superchill-freezing tests show that superchilled storage of haddock at −2°C (28°F) is not compatible with the preparation of packaged haddock products intended for frozen storage. Therefore, initial superchilled storage of haddock at −2°C (28°F) is not recommended if the final processed product is to be subjected to frozen storage.

Ranken (Spain): I got the impression from Carlson's review paper as it was presented to us, that the authors are, perhaps, a little bit sceptical as to whether there is much value in superchilling in the context of North American fisheries. There is certainly no reason for scepticism regarding superchilling in the context of the Portuguese fishery and particularly the method of marketing. The question of freezing after superchilling would not arise in Portugal or in some other countries. Also, of course, they're dealing with entirely different varieties and I think these varieties are, undoubtedly, very much improved by superchilling compared with the often shocking condition of fish after a long voyage to the Mauritanean banks. From the engineering point of view, Scarlatti's version is an expensive system. There is another slightly cheaper version but basically the two principles are the same, that of surrounding the fish with brine coils and cooling by conduction. Now I'd like to hear what is being done using an air circulation system in the United Kingdom. This is another possibility for maintaining a very constant temperature which is very difficult but which, as Love and others have indicated, must be done. The trouble, at the moment, is that most of the systems have a big variation in temperature between about 0°C (32°F) and anything down to −4° or −5°C (25° or 23°F). This may be all right for salmon but it certainly isn't for cod, or for the fish in the Mauritanean grounds.

Merritt (U.K.): In his review, Carlson has summarized our results and conclusions. In view of recent work and some earlier results in the United Kingdom, we also agree with the conclusions in the report by Carlson, Peters and Lane, except that frozen material from superchilled fish may have some limited use, for example in fish cakes. It should be emphasized that although the scientist may look upon the technique of superchilling as one of freezing, in application it is very much a chilling technique. That is to say the storage life is short compared with freezing to −30°C (−22°F). It is unlikely to have a great effect on the trend toward freezing at sea in the United Kingdom distant water fleet.

It may be of some use, however, in improving the performance of some existing wet fishing ships by permitting an extension of voyage. The White Fish Authority plans to make a simple installation employing boxes with recirculation of air in a wet fishing vessel in order to conduct a trial in the near future. The first one-third of the catch will be superchilled. The boxes are designed so that there are small clearances between boxes in a stack, through which cooled air can circulate, as often done in the cooling of cargo. One of the advantages of boxing is ease of discharge. The fish are iced in the usual way. There will almost certainly be no dehydration problem. The main problem may well be the handling of the fish for processing on shore, which is more complicated than in the market in Portugal.

Love (U.K.): May I first put a quotation right for the record? Elerian and I are quoted as saying that the rate of protein denaturation in fish frozen at −30°C (−22°F) is maximal during storage at −1.5°C (29°F), "possibly due to the increased concentration of tissue salts due to removal of water as ice". In fact, though, it has been shown that the rate of denaturation increases as the storage temperature increases, and we suggested that −1.5°C (29°F) was the top of the scale because above it a large proportion of the ice disappeared and the tissue salts became sufficiently diluted to more than counterbalance the other effect.

The paper of Powers *et al.* illustrates, to a nicety, the difficulties of storing fish at an exact temperature, and how the fish purporting to be at −0.5°C (31°F) in air in fact ended up at −1.1°C (30°F). For the purpose of this paper, it was a good thing that the temperature did drop, since otherwise the fish would not have frozen at all, assuming the water and ion concentrations were the same as those of North Sea cod. We found that North Sea cod frozen at −30°C (−22°F) always contained a residue of ice if they were stored at −1°C (30°F), but if they were stored at −0.5°C (31°F) they gradually thawed out over a period of days.

It was encouraging to hear of the prolongation of storage life by superchilling, but what a pity that the effects of drying and the true effects of superchilling were so inextricably mixed up! Drying could have been avoided by wrapping, and then we could have seen the effects caused solely by the temperature. If the authors are continuing this interesting work, may I suggest that the fish be wrapped? This would also presumably avoid the unwanted fluctuation of temperature.

Another point is that, in this kind of work, it is very difficult to freeze fish close to the melting point. We use a liquid bath at −3°C (27°F), sealing the samples in polythene bags, but take the fish out as soon as some ice has definitely formed, so probably very little of the muscle reaches −3°C (27°F). However, in today's paper, a pre-chilling temperature of around −11°C (12°F) was used, which is quite low enough to cause rapid toughening when the temperature is raised afterwards. All of each fillet was cooked, and it seems likely that much of the tail would have cooled well below −3°C (27°F) in the pre-chilling stage, since the temperature of −3°C (27°F) was measured in the thickest part of the fish. Our latest results, which still need repeating, seem to show that, at a steady temperature of −3°C (27°F), there is not much organoleptic or objective difference in the texture during storage between fish frozen at −30°C (−22°F) and those frozen above −3°C (27°F), in contrast to the big difference that we found at −2°C (28°F). These results are tentative but they seem to show the existence of a change-over point below which superchilling is probably not worthwhile.

Kelly (U.K.): Love has proposed an explanation for the better storage behaviour of "shallow" frozen fish compared with "deep" frozen fish when both are held at temperatures just below the melting point. This is based on the premise that the salt concentration in "shallow" frozen fish at −2°C (28°F) is within a critical range equivalent to 3 to 6 per cent NaCl, which favours solubilization of the structural proteins, while the salt concentration in deep frozen fish is greater than this range.

There are two comments I should like to make on this. Firstly, in partially frozen fish, the unfrozen aqueous phase is in equilibrium with ice. In other words the vapour pressures of the ice and the aqueous phase are the same. Since the vapour pressure of ice at any given temperature has a fixed value, the vapour pressure of the aqueous phase, and hence the osmotic concentration, must also have a fixed value. This means that the osmotic concentration of the unfrozen aqueous phase at a given temperature will be the same for all fish, whatever its freezing history. Hence, there can be no differences in tissue salt concentrations between deep and shallow frozen fish held at the same temperature.

Secondly, on the question of actual concentration of the aqueous phase in superchilled fish: it can be calculated that the concentration of the unfrozen fish at −2°C (28°F) is 1.08 osmolal. This is roughly equivalent to 0.54 molar sodium chloride, about 3 per cent and represents the maximum possible concentration of salt at −2°C (28°F). At −1.6°C (29°F) it would only be equivalent to 2.4 per cent NaCl. This assumes that all of the dissolved substances are ionic, which is probably not the case and, hence, true salt concentrations will be even less than the values I have quoted.

It would, therefore, seem that another explanation for the difference in behaviour of deep and shallow frozen fish must be found.

Scarlatti (Portugal): Commenting on Love's remarks that experiments on superchilling fish between the temperatures of −1° and −3°C (30.2° and 26.6°F) by the circulation of cold air have caused dehydration of the fish, I should say that the experiments have not been carried out as they should. Aside from the detrimental effect of blowing air over the fish, the method calls for chilling, not between two temperatures, but at one well controlled temperature. It is known that temperature gradient is a very important cause of dehydration. If this differential exists, there will be dehydration. In the system which we have invented and applied in Portuguese fishing trawlers, the temperature is maintained practically constant and uniform at a selected level. It is not enough just to blow cold air; one must achieve this close temperature control.

Referring to Kelly's objections, I must say that refrigeration at temperatures in the neighbourhood of the freezing point of fish enables its preservation (a) in optimum condition at −1°C (30.2°F) for 21 to 22 days, (b) in good condition at −2°C (28.4°F) for 25 to 26 days and (c) in acceptable condition at −3°C (26.6°F) for 35 to 36 days.

Experiments initiated by the Torry Research Station after Shewan and Merritt's visit to Lisbon have entirely confirmed our findings. There are several reports based on the Torry study, including one by the White Fish Authority. If I had enough time, I would illustrate my point by quoting from the White Fish Authority's report. The results are of interest in spite of the fact that superchilling was applied in such a way that the hold storage capacity was reduced by 25 per cent. Actually, superchilling does not pretend to enter the area of freezing and therefore should not be used at other than its proper temperature. The fact that in a storage time of 15 to 16 days, fish kept only in melting ice reaches the extreme limit of eating quality is recognized by the White Fish Authority in fixing 12 days as the limit below which superchilling should be unnecessary.

Even if one considers 21 days the limit of the keeping time of fish in optimum conditions at −1°C (30.2°F), a further nine days would be available for fishing. This means an increase in catch per fishing trip of 70 to 80 t, with a correspondingly greater income. Furthermore, the cargo capacity will be increased because only 0.3 to 0.4 kg of ice per kg of fish is required in superchilling, as against 1 to 1.2 kg used in the conventional method. The discarding of spoiled fish will also be largely reduced.

Adding up these benefits, an increase of about 40 per cent in the gross income per fishing trip will be obtained. This answers Ranken's objection to the price of the installation, since it is not only the investment that should be considered, but also the increase in revenue which it brings. In this case it is so great that the installation is paid off in a short period.

Costa (Portugal): The reason for several Portuguese fishing trawlers' adoption of the superchilling technique, which is, after all, nothing more than an extra aid to the preservation effect of ice, was the fact that the majority of vessels were too small to accommodate equipment capable of freezing a minimum of 10 to 15 t of fish per day and yet too large to operate in the nearer fishing grounds which produce very low yields.

When the problem of fish utilization arose 15 years ago, because of the extension of fishing trips, the first step was the installation of bare pipe cooling grids in the ceiling, on the ship's sides and bulkheads and, finally, in latter years, on all the partitions of the fish rooms—a logical development. By these means, fish wastage due to bacterial spoilage has reduced and, consequently, fishing trips could be extended by at least one more week and the tonnage of the catch thereby increased. Nevertheless, keeping the whole cargo of ice plus fish, which has a low heat transfer coefficient, at a uniform temperature between the limits of −1° and −3°C (30.2° and 26.6°F) was practically impossible. Finding that the fish furthest away from the cooling system continued to spoil when working between these temperature limits, the skippers and first mates started using lower and lower temperatures and thus originated partial slow freezing of the cargo. Consequently, the greater part of the rejected fish was then due to softening of the flesh of species with weak tissue structure, such as hake and perch and immature fish. Only large-sized fish with firm texture were benefiting from the technique. For this reason, the skippers of the majority of these vessels preferably catch these latter species. When they have to catch other fish, they rely almost exclusively on icing and not on the cold produced by the superchilling equipment.

Unfortunately, my experience as a fishery technologist and as administrator of the largest Portuguese fishing company compels me to state that superchilling is far from being the answer to the ship owners' problems. If, on the one hand, it has some advantages for the Portuguese fisheries, on the other hand, it has posed problems for which solutions have not yet been found.

PART II

FREEZING AND PROCESSING FROZEN FISH

PHYSICAL EFFECTS OF FREEZING FISH

Aspects physiques de la congélation des poissons *A. Gac*

Influence of Freezing and Cold Storage on the Submicroscopical Structure of Fish Muscle . *A. Liljemark*

Discussion

SPECIFIC PROBLEMS AND TECHNIQUES IN FREEZING FISH

Freezing of Shellfish . . *P. Hansen and J. Aagaard*

A Comparison of the Quality of Frozen Plaice Fillets Prepared from Fresh or Frozen Raw Materials *P. Hansen*

Discolouration of Tuna Meat and Red-skin Fish During Frozen Storage *K. Amano, M. Bito and N. Tsukuda*

Discussion

THE EFFECT OF POLYPHOSPHATE TREATMENT

The Effect of Brining and Polyphosphate on Yield and Quality . . . . . *W. J. Dyer*

Polyphosphate Treatment of Cod Muscle *A. H. Sutton*
(with addendum—Bacterial contamination of fillets due to polyphosphate dipping by A. H. Sutton and J. I. W. Anderson)

Discussion

FREEZING OF TROPICAL FISH

Freezing of Tropical Fish . . . *A. N. Bose*
(with addendum—Refrigerated sea water in the preservation of tropical fish)

Factors Influencing Quality of Frozen Fish at Sea in Subtropical and Tropical Areas. *E. Kordyl and Z. Karnicki*

Discussion

THAWING FROZEN FISH

Evaluation of Techniques and Equipment for Thawing Frozen Fish . . . . . *J. H. Merritt*

Thawing of Frozen Fish in Water . . *M. R. Hewit*

Essai d'application de la méthode de décongélation électronique à la sardine congelée destinée à la conserve *J. R. Crépey and D. Mairey*

Influence of Thawing and Thawing Methods on the Immediate and Refrozen Storage Quality of Fish *W. A. MacCullum and D. R. Idler*
(with addendum—Green discoloration in flounder by H. C. Freeman and D. R. Idler)

Discussion

Aspects physiques de la congélation des poissons

par A. Gac

Aspects physiques de la congélation des poissons

L'auteur étudie les principaux phénomènes physiques dont les tissus de poisson sont le siège au cours de leur congélation, et spécialement, la formation de la glace en fonction de la température et la distribution des cristaux en fonction de la vitesse du refroidissement.

L'auteur présente les variations de l'enthalpie et celles de la conductivité thermique des muscles de poisson.

Il discute l'influence des conditions de transmission de la chaleur sur le coefficient d'échange en surface. Enfin, il étudie les paramètres intervenant sur la durée de l'opération de congélation.

Physical aspects of fish freezing

The writer has studied the main physical phenomena occurring in fish tissues during freezing, particularly ice formation as a function of temperature, and distribution of crystals as a function of the speed of freezing.

The author describes enthalpy variations and changes in the thermal conductivity of the muscles of fish.

He discusses the influence of heat transmission conditions on the coefficient of surface exchanges. Finally, he studies parameters affecting the duration of the freezing process.

Aspectos físicos de la congelación de pescado

El autor estudia los principales fenómenos físicos que tienen lugar en los tejidos del pescado durante su congelación y, especialmente la formación del hielo en función de la temperatura y la distribución de los cristales en función del enfriamiento.

El autor presenta las variaciones de la entalpia y las de la conductividad térmica de la carne del pescado.

Examina la influencia de las condiciones de transmisión del calor sobre el coeficiente de cambio en la superficie. Por último, estudia los parámetros que intervienen en la duración de la operación de la congelación.

L'EAU étant, dans les tissus d'origine biologique et en particulier dans les poissons et filets de poisson, l'élément de loin le plus important en masse, on peut assimiler, pour l'essentiel, la congélation à la solidification de solutions aqueuses diluées. Cependant, la complexité de l'architecture cellulaire fait que les mécanismes sont en réalité plus complexes et que souvent ils interfèrent entre eux.

Cette note, a pour objet l'étude des phénomènes et caractères essentiels de la physique de la congélation des poissons.

(1) L'état de l'eau dans les muscles du poisson.

(2) La congélation ayant pour effet de séparer l'eau sous forme de glace pure des autres constituants cellulaires, on étudiera la relation entre la température et la proportion d'eau gelée.

(3) La répartition des cristaux et leur dimension dépendent des conditions d'échanges thermiques. L'influence de la vitesse du refroidissement sur la cristallisation de la glace.

(4) La formation de la glace entraîne des modifications plus ou moins profondes des caractéristiques physiques des tissus. L'estimation de la variation d'enthalpie et de la conductivité thermique des tissus en fonction de la température.

(5) Les paramètres qu'il convient de prendre en considération dans la détermination de la puissance thermique mise en jeu au cours de la congélation.

TENEUR EN EAU DES MUSCLES DE POISSON

L'eau joue un rôle important dans la conservation des produits; elle est, en particulier, l'un des agents responsables de la grande altérabilité des tissus d'origine biologique.

La teneur en eau des muscles de poisson peut être assez largement variable selon les espèces, l'âge des individus, la période du cycle sexuel, les conditions de vie, etc.

Dans un même poisson, il existe des différences sensibles de teneur en eau selon la région du corps.

En général, pour les *poissons maigres*, tels que la morue, la teneur en eau est de l'ordre de 80 à 84 pour cent de la masse des muscles (fig 1).

Pour les *poissons gras*, dont la chair est riche en huile, l'eau peut représenter de moins de 60 pour cent à environ 80 pour cent de la masse des muscles; cet écart important est dû aux variations de l'état d'engraissement des individus (fig 2).

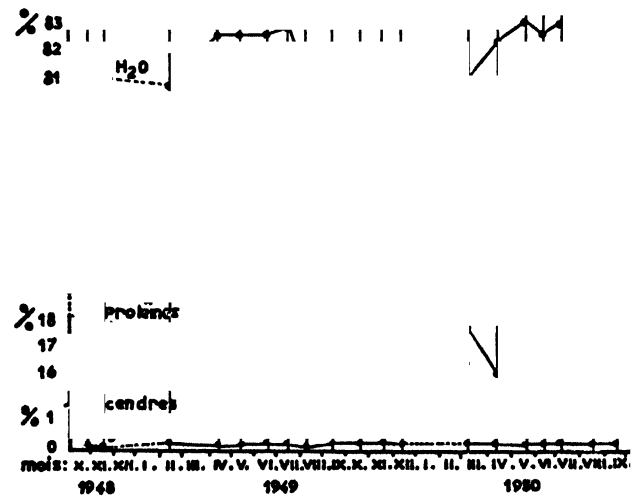


Fig 1. Variation de la teneur en eau, en protéines, cendres et graisse des muscles de morue (d'après Kordyl, cité par F. Soudan)

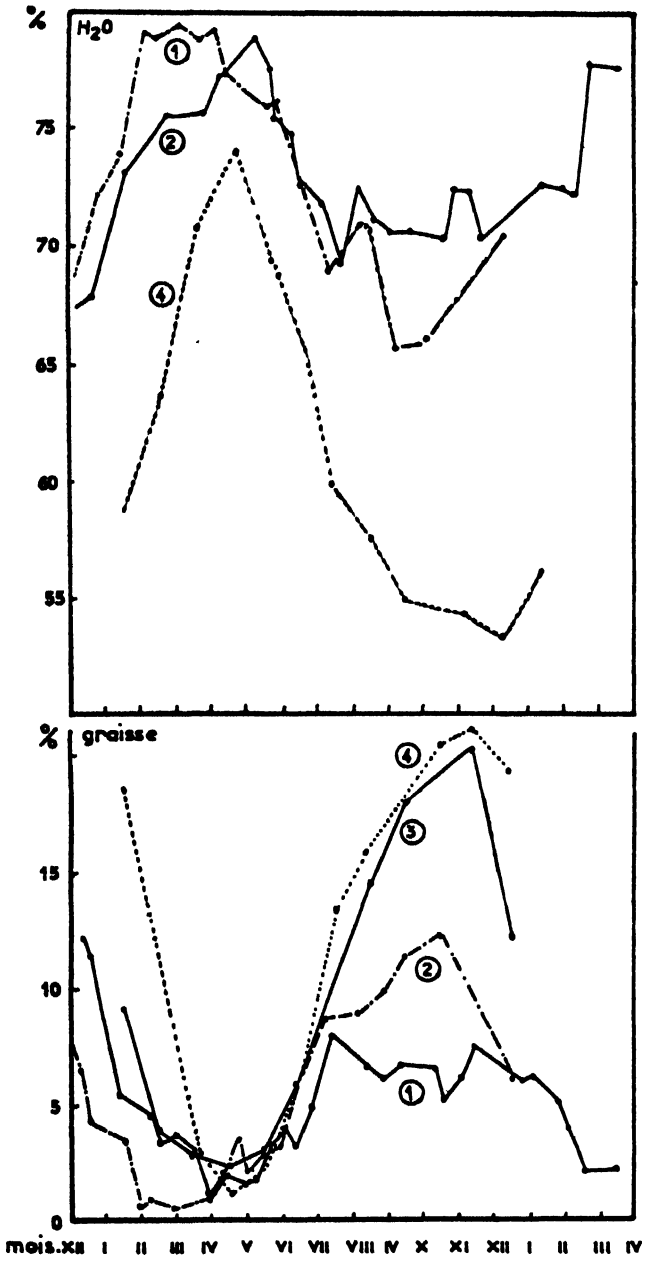


Fig 2. Variation de la teneur en eau et en graisse des muscles de sardines

(1) golfe de Gascogne (1942)
(2) Côte Cantagrique (1946)
(3) Cornouailles (1936)
(4) Maroc (1951) (d'après F. Soudan)

La teneur en eau des autres produits de la mer est voisine de 80 pour cent (crevettes 79 pour cent, huîtres 80 pour cent, etc.).

L'eau existe dans les tissus sous diverses formes. Elle est *libre* dans les solutions cellulaires; elle est *liée* de façon plus ou moins énergique dans les divers complexes colloïdaux macromoléculaires qui sont responsables en partie de la texture et de la tenue mécanique des tissus. En outre, elle peut former, dans des conditions définies de température et de concentration des *hydrates* avec certaines substances.

Les recherches entreprises concernant la détermination de la répartition entre l'eau libre et l'eau liée se sont avérées difficiles et délicates. Les résultats ne concordent pas parfaitement, à la fois à cause de la diversité des tissus et des processus expérimentaux adoptés. Cependant, de façon générale, l'eau libre représente, selon les tissus de 5 à 25 pour cent de l'eau totale de la substance. Malgré l'imprécision concernant les mesures, il apparaît que la réserve essentielle est constituée par l'eau comprise dans les gels et les pseudo-solutions.

Il convient donc de ne pas assimiler trop hâtivement le mécanisme de la congélation à celui de la congélation d'une solution aqueuse ne renfermant qu'une seule substance dissoute.

Les combinaisons hydriques sont telles qu'elles forment un système en état d'*équilibre* ou tendent vers un état d'équilibre; cet équilibre existe non seulement à l'intérieur de chaque cellule, mais aussi pour l'ensemble d'un tissu, car l'eau peut migrer à travers les parois cellulaires. Si, pour une raison quelconque, l'équilibre est rompu par diminution ou accroissement de l'un des éléments du système, il y a déplacement de l'eau, tendant à ramener le système vers un nouvel état stable.

En particulier, si la teneur en eau disponible diminue, les solutions cellulaires se concentrent. Elles deviennent hygroscopiques et mobilisent l'eau comprise dans les ensembles colloïdaux. Ceux-ci peuvent être, selon le degré de liberté de l'eau, plus ou moins déshydratés. Inversement, si la teneur en eau revient vers la teneur initiale, les solutions se diluent; les structures colloïdales se reconstituent. Cette reconstitution peut être plus ou moins complète. En particulier, après une déshydratation poussée, la *réimbibition* peut être imparfaite; la teneur en eau du tissu réhydraté est moindre que celle du tissu frais. L'aptitude d'une substance à être ramenée dans son état initial dépend de la substance, du taux de siccité atteint et aussi des processus de déshydratation et de réimbibition adoptés.

RELATION ENTRE LA PROPORTION DE GLACE ET LA TEMPERATURE

Quand un poisson ou un filet est refroidi, il apparaît pour une certaine température, dite de *congélation commençante* θ_c les premiers cristaux de glace d'eau pure. En fait, la cristallisation a lieu après un certain temps de *sous-refroidissement*. Lors de la formation de la glace, un réchauffement se produit jusqu'à une température voisine de θ_c.

Tout au début de la congélation, le comportement d'un tissu peut être assimilé à celui d'une solution aqueuse.

Or, il est connu que, pour une *solution étendue*, non électrolysable, l'abaissement $\Delta\theta$ de la température de congélation commençante de la solution par rapport à la température de congélation du solvant pur (eau 0°C, 32°F) croît avec le titre moléculaire de la solution.

Raoult, en 1830, a exprimé cette règle par la relation suivante:

$$\Delta\theta = C\,T\,m$$

où C est une constante dépendant de la matière du solvant ($C = 18{,}5$ par l'eau).

Tm est le titre moléculaire de la solution (nombre de molécules de la substance dissoute du nombre total de molécules dans la solution).

Deux solutions ayant le même titre *Tm* ont donc même abaissement $\Delta\theta$.

S'il s'agit d'électrolyte, l'abaissement $\Delta\theta$ est augmenté en raison de la dissociation des molécules.

Les concentrations massiques de solutions ayant même abaissement $\Delta\theta$ dépendant de la masse moléculaire et de la nature chimique des substances dissoutes sont nécessairement différentes. Par exemple, pour un abaissement $\Delta\theta$ de 1°C (33.8°F), une solution de chlorure de sodium renferme 1,7 g de sel pour 100 g d'eau et une solution de saccharose 17,03 g de sucre pour également 100 g d'eau.

Cette remarque justifie les différences observées entre tissus végétaux et animaux. Dans les fruits et légumes qui renferment environ 80 pour cent d'eau, en masse, et qui sont riches en glucides solubles, la température de congélation θ_c est généralement inférieure à −1,5° ou −2°C (29.3° ou 28.4°F) et atteint −3,5°C (25.7°F); dans les poissons comme d'ailleurs dans les viandes maigres, la température de congélation commençante est de l'ordre de −1°C (30.2°F) et dans de rares cas, atteint −1,5°C (29.3°F).

A partir du moment où la congélation est amorcée, il existe nécessairement un équilibre entre la concentration des solutions résiduelles et la température: *les solutions sont nécessairement saturantes.* Chaque fois que la température diminue ou augmente, il y a formation de glace et concentration des solutions ou fusion de glace et dilution des solutions.

Au début de la congélation, entre −1° et −2°C, dans le cas des muscles de poisson, la glace formée représente environ la moitié de la teneur totale en eau. Cette observation montre que, dès le début, une fraction importante de l'eau liée est mobilisée et est congelée. Au fur et à mesure que la température diminue, la proportion d'eau gelée augmente, par contre, la masse de glace formée par °C diminue.

Vers −20°C (−4°F) la très grande majorité de l'eau est à l'état de glace; la phase de solidification de l'eau peut être considérée achevée. Ceci ne signifie pas cependant qu'à plus basse température aucun phénomène de cristallisation n'aura lieu.

L'*humidité résiduelle* du liquide interstitiel et des colloïdes représente, selon les auteurs, de 5 à 9 pour cent du contenu total d'eau. Aux températures ordinaires de l'entreposage industriel, les produits renferment donc une petite quantité d'eau, qui, étant fortement liée aux albumines, n'est pas congelée. Riedel estime cette fraction à 0,39 kg/kg de matières sèches.

Finalement, compte tenu de l'eau non congelable, la proportion d'eau gelée à −20°C représente en pratique 99 pour cent de l'eau mobilisable.

Le tableau 1 présente la proportion d'eau glacée dans les muscles de poisson selon divers auteurs; il montre l'existence d'une certaine dispersion. De plus, au-dessous de −10°C, les valeurs calculées par application de la loi de Raoult sont supérieures aux valeurs expérimentales. Bien que la loi de Raoult ne s'applique bien que dans le cas de solutions diluées, il est normal qu'au fur et à mesure que s'opère la concentration des constituants cellulaires, l'eau restante soit de plus en plus énergiquement liée. Elle est donc moins facilement rendue disponible.

Si l'on observe que la majeure partie de l'eau est congelée entre −1° et −10°C, la concordance entre le calcul et l'expérimentation est suffisamment bonne pour qu'en pratique on puisse estimer que les muscles de poisson se congèlent comme une solution de concentration moléculaire telle que la température de congélation commençante soit de −1°C.

La congélation de l'eau se fait avec *augmentation de volume.* Cette augmentation est de l'ordre de 6 pour cent environ. Selon l'importance des méats l'accroissement de volume est en réalité plus faible (Kuprianoff). Cependant, si l'on désire que le produit congelé ait une forme régulière, il peut être nécessaire de le brider (congélation en plaques par exemple).

Jusque vers −20°C, seule l'eau est solidifiée; si l'on poursuit le refroidissement au-dessous de cette température, les premiers *eutectiques* apparaissent, ce qui entraîne une certaine diminution de la concentration des solutions résiduelles.

Pour obtenir la *solidification totale* d'un tissu et ainsi éliminer l'influence néfaste de la phase liquide, la substance doit être amenée à des températures inférieures à −50°C (−58°F), de l'ordre de −70°C (−94°F). Il y a, en effet, des retards plus ou moins importants, à cause du phénomène de la surfusion. Il s'agit d'une véritable "trempe", selon l'expression de L. Rey, destinée à déclencher la cristallisation des divers composés. Après ce refroidissement à très basse température, la substance peut être réchauffée vers −50°C.

Ce traitement n'est actuellement pas utilisé pour l'entreposage frigorifique. Cependant, comme avec les progrès techniques, les moyens de l'industrie sont de plus en plus puissants, on peut imaginer que dans quelques années on pratiquera normalement en fin de congélation une véritable "trempe frigorifique", des poissons et spécialement des poissons gras.

TABLEAU 1. PROPORTION D'EAU CONGELÉE DANS LES POISSONS

Température de congélation commençante	*Proportion d'eau congelée par rapport à la teneur totale en eau à*					
	−5°C	−10°C	−15°C	−18°C	−20°C	*Observations*
−1°C	0,8	0,91		0,95	0,96	*Loi de Raoult*
−1°C	0,80	0,90		0,95		Morue (1)
−1°C			0,93	0,935		Eglefin (1)
	0,76	0,84	0,88		0,90	Cabillaud (2)

(1) D'après Frost et Carter, cités par F. Soudan.
(2) D'après Riedel, cité par R. Plank.

CRISTALLISATION ET PUISSANCE THERMIQUE

Si la proportion d'eau congelée à l'équilibre dépend du niveau de température et non du processus adopté pour atteindre cette température, la répartition et la dimension des cristaux sont liées à la puissance thermique mise en jeu.

Il est bien connu, depuis longtemps que si la puissance est petite, la congélation progresse lentement.

En congélation dite lente, les premiers cristaux de glace apparaîssent à l'extérieur des cellules qui sont soumises ainsi à un effort mécanique et à un accroissement de pression osmotique. L'eau intracellulaire diffuse, à travers les membranes, vers les cristaux dont le volume augmente.

Les cellules sont lésées plus ou moins gravement, tant par suite de l'apparition du déséquilibre osmotique que par la présence des formations cristallines plus ou moins régulières.

Si le refroidissement est poursuivi lentement, vers −10°C, des cristaux se forment à l'intérieur des cellules elles-mêmes.

En congélation rapide ou ultra-rapide, les centres de cristallisation apparaîssent à l'entérieur des cellules; ces cristaux sont nombreux et petits, les solutions résiduelles forment un réseau maillé, enrobant les cristaux de glace et les colloïdes plus ou moins déshydratés.

Plus la congélation est conduite rapidement, c'est-à-dire plus l'écart de température entre la substance et le milieu est grand, et plus fin est le feutrage de cristaux intracellulaires.

Non seulement la distribution mais aussi la *géométrie des cristaux* dépendent de la rapidité du refroidissement, c'est-à-dire de la puissance thermique échangée. Divers auteurs (Dowell et Rinfret, Luyet) ont montré l'existence de différents types de formations cristallines (formation hexagonale, à dendrites irréguliers, à sphérules, formation évanescente).

Quand un tissu biologique est amené à la température de congélation commençante, il n'y a pas cristallisation immédiate; celle-ci ne se produit que s'il existe un certain *sous-refroidissement*; autrement dit, les solutions passent d'abord par un état métastable de surfusion (fig 3).

Quand les premiers cristaux apparaîssent, la congélation se propage rapidement. La *vitesse de propagation* dépend de la surfusion et du titre moléculaire des solutions.

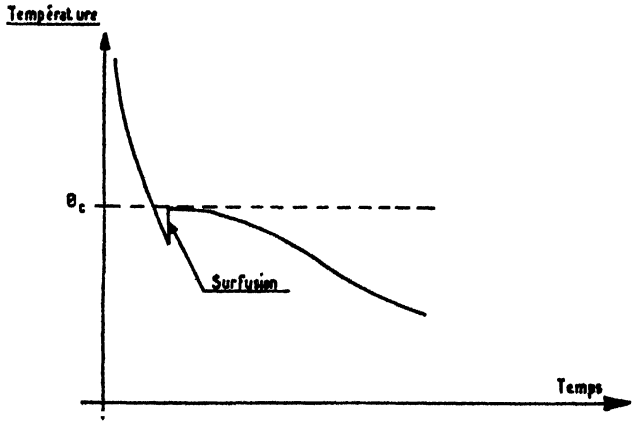


Fig 3. Représentation schématique de l'évolution de la température au cours de la congélation

Dans le cas d'*eau pure*, placée dans un tube, la vitesse linéaire de cristallisation augmente avec la surfusion (fig 4). On montre d'ailleurs que la vitesse de cristallisation V d'un fluide satisfait la relation suivante:

$$V = k\frac{s}{\eta}$$

où k est une constante dépendant de la nature du liquide
s la surfusion
η la viscosité du liquide.

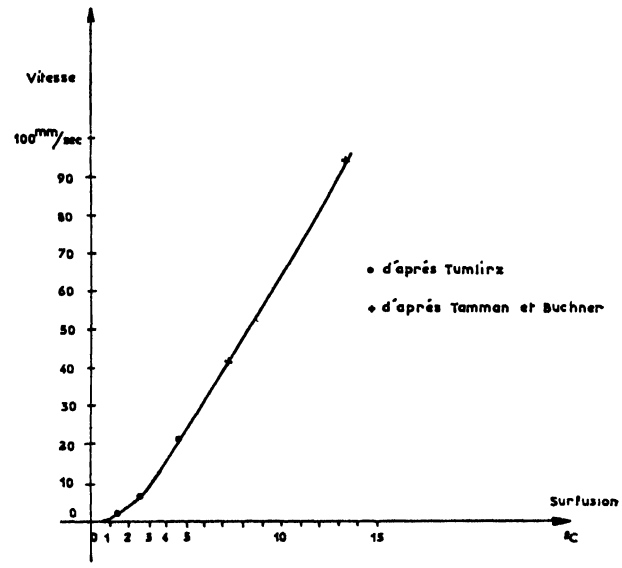


Fig 4. Variation de la vitesse linéaire de cristallisation de l'eau pure en fonction de la surfusion

Pour l'eau pure, la propagation de la solidification est rapide. Il en résulte un véritable choc quand est amorcée naturellement ou est provoquée la cristallisation.

Pour une *solution aqueuse, diluée* la vitesse de cristallisation est plus faible que pour l'eau pure. Par les mêmes conditions de cristallisation maximale, l'écart entre la vitesse de cristallisation de l'eau pure et celle de la solution augmente comme la racine carrée de titre moléculaire de la solution (règle de Von Pickardt).

Si la *solution est concentrée* (titre supérieur à 0,10), la vitesse décroît au fur et à mesure qu'augmente le titre en corps cristallisant. Par exemple, pour un titre de 0,335, la vitesse de cristallisation est de 0,17 mm/sec à −8,7°C (16.3°F). A cette température pour l'eau pure, la vitesse serait de l'ordre de 50 mm/sec.

Dans les *tissus des poissons*, le titre moléculaire des solutions est assez faible (0,01); la cristallisation étant d'autant plus rapide que la surfusion est plus grande et le titre plus petit, il en résulte qu'au moment où la cristallisation est amorcée, les cellules sont soumises à un véritable *choc osmotique*: les solutions cellulaires deviennent très fortement hypertoniques, alors que les complexes colloïdaux sont encore hydratés. L'équilibre de l'eau dans les tissus est très brutalement détruit au moment même de l'apparition des centres de cristallisation et de la formation de la glace.

De ce qui précède, on pourrait conclure que la congélation lente est moins néfaste que la congélation rapide. Il est exact qu'à la suite d'un refroidissement lent et

modéré, il n'apparaît que de la glace extra-cellulaire; les lésions sont limitées; un tissu vivant ainsi congelé peut n'être pas tué. Mais, en pratique, la température d'entreposage étant non supérieure à −20°C, il y a formation de glace intracellulaire; d'autre part, la cristallisation ne se produisant qu'après sous-refroidissement de la substance, celle-ci est inévitablement l'objet de l'agression osmotique, même si la congélation est lente. En contre-partie, il est toujours souhaitable que la durée d'application des conditions toxiques soit la plus courte possible. Ainsi, par refroidissement, avec une rapidité de plusieurs centaines de °C/seconde, jusqu'à −130° à −150°C (−202° à −238°F), l'eau se transforme à l'état amorphe; les lésions cellulaires sont suffisamment minimes pour que le tissu puisse rester en vie (L. Rey).

Les conséquences du choc osmotique peuvent être atténuées dans certaines conditions. Par exemple, on peut par un artifice approprié, introduire dans le protoplasme une *substance protectrice.*

J. Rostand a le premier recommandé l'emploi du glycérol qui diffuse facilement à travers les parois des cellules, se dissout dans les solutions en augmentant leur concentration, abaisse la température de congélation commençante, ne cristallise pas aux températures de congélation de la majeure partie de l'eau, diminue la vitesse de cristallisation. Dans ces conditions, le choc osmotique est suffisamment atténué et les lésions conséquentes suffisamment limitées pour préserver la vie des cellules ou du tissu (L. Rey).

Du seul point de vue physique, on ne peut pas caractériser deux processus de congélation industriels aptes à fournir des produits congelés de caractéristiques fondamentalement différentes.

Les *techniques industrielles* de congélation de poissons et filets de poissons sont finalement suffisamment rapides pour favoriser la congélation intracellulaire de l'eau et ainsi limiter les risques de déchirures de membranes et d'exsudation au moment du réchauffement, mais beaucoup trop lentes pour éliminer les dégâts résultant du choc osmotique.

CARACTERISTIQUES THERMIQUES DES MUSCLES DE POISSON AU COURS DE LA CONGELATION

Les caractéristiques thermiques d'une substance congelée sont fonction de la proportion de glace en cours de formation ainsi que de la glace déjà formée; ces caractéristiques sont donc dépendantes de la nature de la substance et de la température.

Les paramètres essentiels à prendre en considération à propos de la congélation sont la variation d'enthalpie correspondant à un abaissement défini de la température et la conductivité thermique.

Variation d'enthalpie

La variation d'enthalpie est la quantité totale de chaleur à enlever à l'unité de masse de produit pour le refroidir depuis une température initiale homogène à une température finale également homogène.

Si le tissu n'est le siège d'aucun changement d'état ou réactions chimiques, la variation d'enthalpie est définie par sa chaleur massique. Refroidi à puissance constante, sa température suit une évolution linéaire du temps.

Si un des constituants du tissu change d'état, et en particulier, si de l'eau est transformée en glace, la

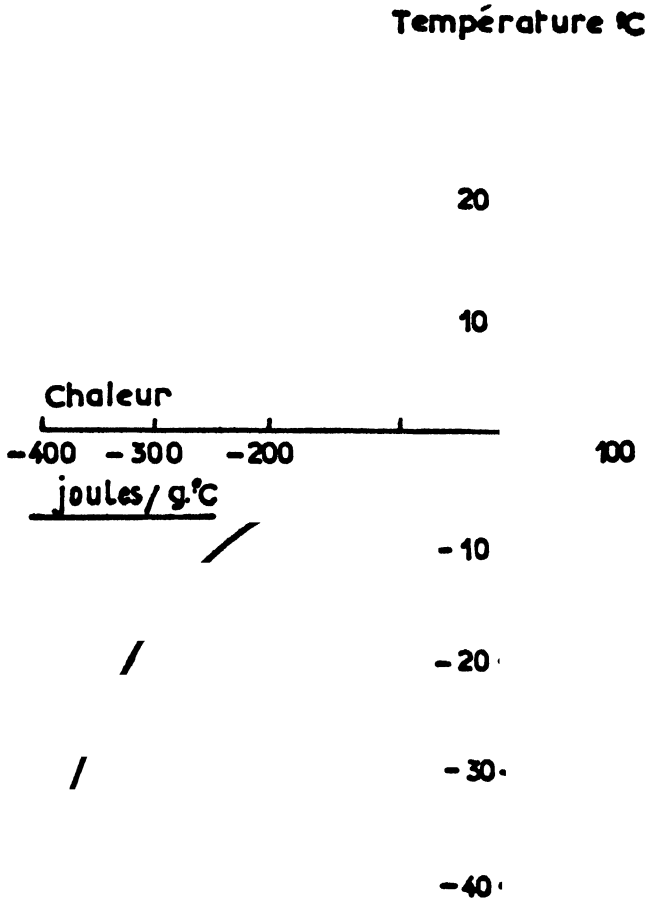


Fig 5. Variation d'enthalpie d'un échantillon de muscle de morue entre 0°C et −40°C. L'origine est zéro à 0°C (d'après Jason et Long)

variation d'enthalpie du tissu entre θ et $(\theta - \Delta\theta)$ peut être dissociée en trois termes:

La chaleur massique sensible de la fraction qui n'a pas changé d'état à θ. Ce terme comprend la chaleur massique de la matière sèche et celle des solutions intercristallines.

La chaleur massique sensible de la glace déjà formée à la température θ.

La chaleur latente de cristallisation de l'eau entre θ et $(\theta - \Delta\theta)$.

On peut adopter la relation suivante:

$$H(\theta, \theta - \Delta\theta) = [c_s m_s + c_L m_L + c_g m_g]\Delta\theta + L\Delta M$$

où $H(\theta, \theta - \Delta\theta)$ est la variation d'enthalpie entre θ et $\theta - \Delta\theta$

c_s c_L et c_g respectivement la chaleur massique de la matière sèche, des solutions et de la glace

m_s, m_L et m_g respectivement la masse de matière sèche, d'eau liquide et de glace à θ par unité de masse de produit

L la chaleur massique latente de congélation de l'eau

ΔM la masse d'eau congelée entre θ et $\theta - \Delta\theta$ par unité de masse de produit.

Bien entendu, la relation ci-dessus suppose que les chaleurs massiques sont constantes, que les proportions d'eau, de glace et de matière sèche sont connues, que le tissu n'est le siège d'aucun autre phénomène thermique. La relation n'est donc qu'une expression approchée.

Toutefois, comme la congélation de l'eau est de loin le phénomène thermique le plus important, spécialement en début d'opération, la relation ci-dessus permet une estimation convenable des puissances à mettre en jeu en adoptant les valeurs numériques suivantes:

$$c_s \neq 0{,}30 \text{ kcal/°C}$$
$$c_L \neq 1 \text{ kcal/°C}$$
$$c_g \neq 0{,}50 \text{ kcal/°C}$$
$$L \neq 80 \text{ kcal/kg}$$

On peut noter que l'étude d'un système en cours de congélation peut être ramenée à celle d'un système n'échangeant que de la chaleur sensible: il suffit que la chaleur massique du second système soit égale à la variation d'enthalpie du premier, exprimée par °C de variation de température. Cette dernière grandeur est souvent appelée pour cette raison: "*chaleur massique apparente*".

Un certain nombre d'auteurs (Jason et Long, Woolrich, Riedel, etc.), ont procédé à la *détermination* expérimentale de la variation d'enthalpie au cours de la congélation des muscles de poisson.

La fig 5 présente, d'après les travaux de Jason et Long, la variation totale d'enthalpie du muscle de morue entre 0 et −40°C. La fig 6 concerne le chaleur massique apparente de muscle de poisson et d'une solution aqueuse de chlorure de sodium à 2,69 pour cent. On note une très bonne concordance, jusqu'à −8°C, entre les résultats relatifs au poisson et à la solution saline.

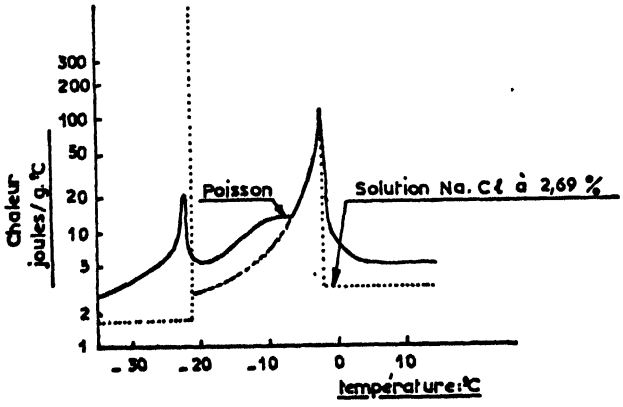


Fig 6. Chaleur massique apparente de muscle de poisson et d'une solution de NaCl à 2.69 pour cent (d'après Jason et Long)

Riedel, a établi des *diagrammes enthalpiques* pour diverses denrées et notamment pour les muscles de poisson maigre (fig 7).

Dans le cas du poisson gras, Riedel propose la relation suivante:

$$\Delta Hpg = g\Delta Hg + (1 - g)\Delta H$$

où ΔHpg est la variation d'enthalpie du poisson gras
ΔHg est celle du poisson maigre lue sur le diagramme
ΔH est la variation d'enthalpie de la fraction grasse pour la différence donnée de température
g est la masse en matière grasse par kg de poisson.

Conductivité thermique

Comme la structure physique du tissu est profondément modifiée au cours de la congélation, la conductivité évolue, dans des conditions considérables.

Un certain nombre d'auteurs ont déterminé expérimentalement la conductivité des muscles de poissons en fonction de la température. La fig 8 représente un certain nombre de résultats. Ceux-ci sont assez dispersés, selon les techniques et selon les échantillons étudiés: à −20°C pour les muscles de poisson maigre, le coefficient de. conductivité est compris entre 1,2 et 1,6 kcal/h m °C Les écarts peuvent également être dus au sens de propagation du flux de chaleur. Ainsi, la conduction selon le sens des fibres est de 15 à 30 pour cent plus grande que selon le sens transversal aux fibres (Lentz).

Certains auteurs ont cherché à définir une *relation* permettant de calculer la conductivité thermique d'un tissu.

Dès 1904, Maxwell donnait la relation suivante applicable à une substance dispersée dans une autre substance.

$$\lambda = \lambda c \left[\frac{1 - \left(1 - a \cdot \frac{\lambda d}{\lambda c}\right) b}{1 + (a - 1).b} \right]$$

où λ est le coefficient de conductivité du mélange
λc le coefficient de conductivité de la phase continue
λd celui de la phase dispersée

$$a = \frac{3\lambda c}{2\lambda c + \lambda d}$$
$$b = \frac{V_d}{V_c + V_d}$$

V_c et V_d sont les volumes respectivement de la phase continue et de la phase dispersée.

La concordance entre les mesures expérimentales et les résultats du calcul est satisfaisante si la proportion de la phase dispersée est petite.

Tchigeov propose une autre relation:

$$\lambda = \lambda o + \frac{A}{1 + \frac{B}{\log T}} \text{ (en kcal/h m °C)}$$

où $\lambda o = 0{,}372$ kcal/h m °C
$A = 0{,}669$
$B = 0{,}148$
T = température absolue de l'échantillon congelé

L'application de la relation Tchigeov fournit des valeurs de λ voisines de 1 kcal/h m °C.

La connaissance de la variation d'enthalpie par °C ou chaleur massique apparente de la conductivité thermique et de la masse volumique (environ 1 020 kg/m³) permet d'estimer la *diffusivité thermique des tissus*. Celle-ci varie très notablement au cours de la congélation et spécialement au début du processus.

PARAMETRES DE LA CONGELATION INDUSTRIELLE

L'opération proprement dite de la congélation dépend de nombreux paramètres: les uns concernent la substance et les autres le fonctionnement de l'appareil de congélation.

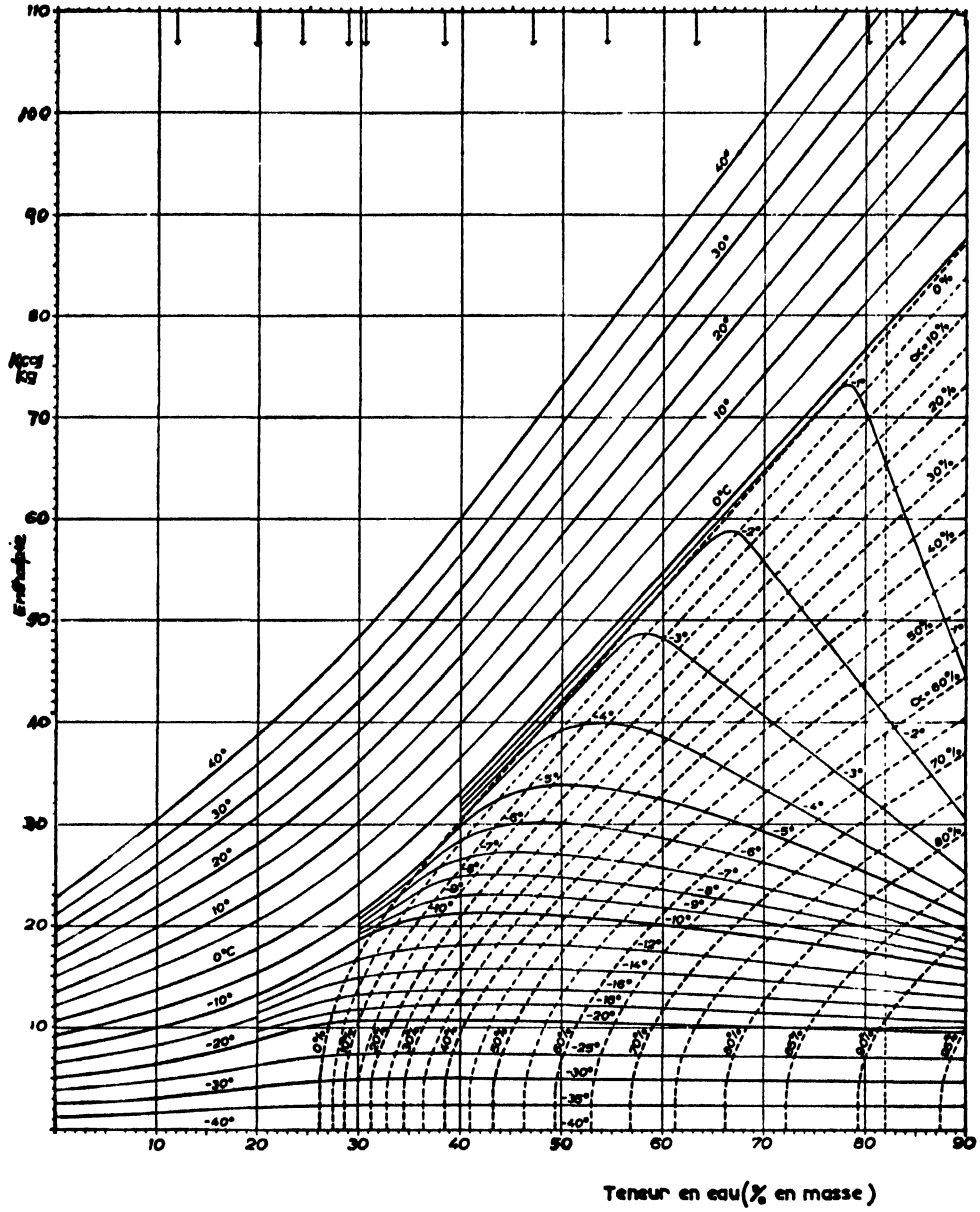


Fig 7. Diagramme enthalpique des muscles de poisson de mer maigre (d'après Riedel)

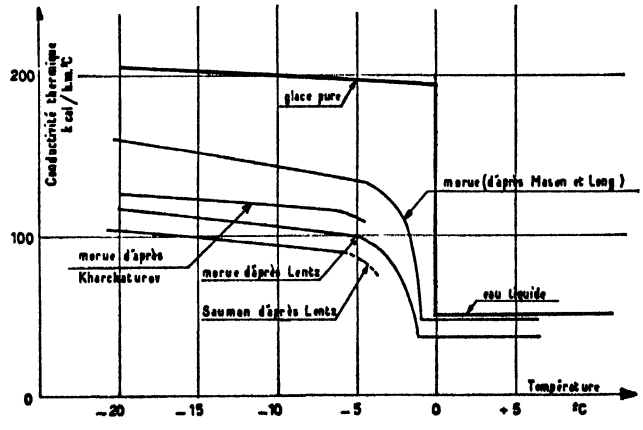


Fig 8. Conductivité thermique de muscle de poisson maigre à basse température

Les paramètres propres à la substance sont:

la définition de sa forme
ses dimensions et notamment son épaisseur
la chaleur massique apparente
la conductivité thermique
le volume massique
les températures initiale et finale

Les paramètres concernant le dispositif de congélation sont:

la température
le coefficient d'échange en surface qui dépend lui-même:
de la nature du fluide
de la vitesse de déplacement
de l'humidité de l'atmosphère, éventuellement
des dimensions de l'objet à congeler

La chaleur massique apparente et la conductivité thermique sont fonction de la température. Par conséquent, ces facteurs varient pendant la congélation dans le temps et selon la région considérée de la substance.

Les autres paramètres, y compris le volume massique, peuvent être supposés constants, en première approximation du moins. En raison du nombre de critères à prendre en compte, la prévision de la durée d'une opération de congélation est particulièrement délicate.

Dans ce paragraphe, nous étudierons spécialement les deux paramètres suivants:

le coefficient d'échange thermique en surface
la durée de la congélation

Coefficient d'échange en surface

L'échange de chaleur entre un tissu et le milieu extérieur dépend en particulier d'une part, du coefficient de conductivité de la substance (cf. conductivité thermique) et, d'autre part, du coefficient d'échange thermique en surface. En particulier, si ce dernier est petit, la durée de la congélation peut être sensiblement augmentée (G. Loerntzen; fig 9).

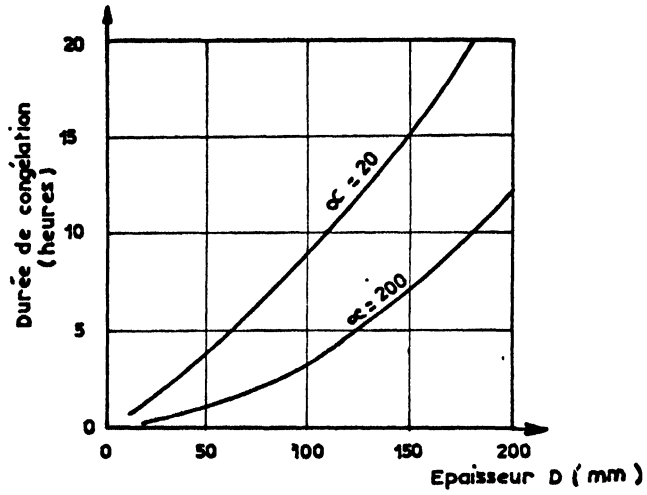


Fig 9. Durée de congélation de plaques de poissons d'épaisseur D en fonction du coefficient d'échange en surface α en kcal/h m² °C (d'après Lorentzen)

Le coefficient α d'échange thermique en surface pour un objet placé dans un milieu fluide satisfait de façon générale une relation de la forme

$$N_u = aP_r^m + b[(R_e)^n.(P_r)^p]$$

où

$N_u = \frac{\alpha D}{\lambda}$ est le nombre de Nusselt

$R_e = \frac{V_q D}{\mu}$ est le nombre de Reynolds

$P_r = \frac{C_p \mu}{\lambda}$ est le nombre de Prandtl

et où a et b sont des constantes; dans le cas de l'air $a = o$

m, n, p sont des paramètres dépendant des conditions du refroidissement. Ils sont inférieurs à l'unité

D est la plus petite dimension (diamètre) de l'objet

λ est le coefficient de conductivité du fluide

V_q est la densité de débit massique

μ est la viscosité absolue du fluide

C_p est la chaleur massique du fluide.

De la relation ci-dessus, il résulte que le coefficient α est exprimé par une équation de la forme suivante:

$$\alpha = \frac{\lambda}{D}\left[a.P_r^m + b(P_r)^p \cdot \frac{(V_q.D)^n}{\mu}\right]$$

Le coefficient α augmente si

l'objet est de petites dimensions: plus la dimension D est petite, pour une forme géométrique définie, et plus rapide est son refroidissement;

la densité de débit V_q croît. Mais, comme l'exposant n est de l'ordre de 0,5 à 0,6 pour un poisson entier, en tunnel et en bain liquide (Nagaoka et Coll; McAdams; fig 10), une augmentation de la densité du débit est

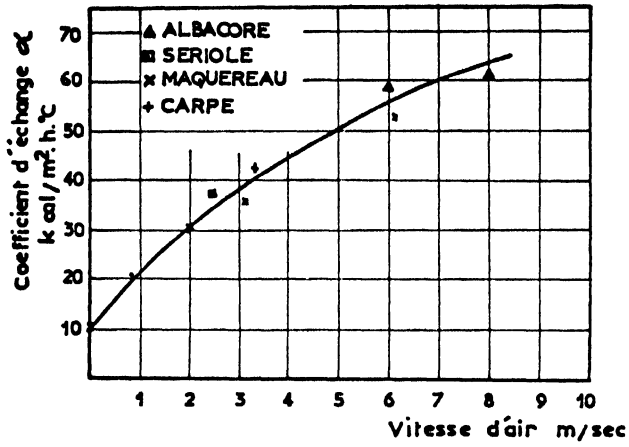


Fig 10. Variation du coefficient d'échange en surface α pour des poissons entiers, en fonction de la vitesse d'air (d'après Nagaoka et Coll)

d'autant moins efficace que la vitesse est plus grande. Par contre, l'énergie nécessaire au brassage augmentant avec le cube du débit, il est évident que, pour chaque produit, il existe un brassage optimal;

le nombre de Prandtl est grand. Pour l'air, le nombre de Prandtl est de 0,725 à −30°C (−22°F); pour une solution de chlorure de calcium à 1,26 de masse volumique, le nombre de Prandtl est de 94,5 à la même température; la congélation en saumure est plus rapide que dans l'air. Cependant, l'emploi de liquides incongelables soulève des difficultés d'ordre technologique, ce qui limite l'intérêt du processus.

Dans le cas de l'air, pour des poissons non protégés par un film étanche à la vapeur, il y a, outre un échange superficiel de chaleur sensible, un échange de chaleur latente par *évaporation d'eau.*

Le coefficient α peut être augmenté nettement au début de l'opération, quand le produit est encore chaud. L'accroissement du coefficient α peut être de l'ordre de 20 à 30 pour cent pour des poissons non emballés.

Avec les *gaz liquéfiés* et spécialement l'azote liquide, il est possible d'augmenter le flux thermique tant à cause

de l'écart considérable de température dont on peut disposer qu'à cause de la valeur du coefficient d'échange en surface. Cependant, l'échange superficiel dépend de l'écart de température existant entre l'objet et le fluide cryogénique (fig 11). Si cet écart est très petit, l'échange a lieu par convection. Si l'écart croît, de petites bulles se forment provoquant une certaine turbulence, ce qui augmente sensiblement la puissance mise en jeu. Si l'écart de température est encore plus grand, les bulles s'agglomèrent et forment un film de gaz tendant à réduire le flux de chaleur. Le flux de chaleur passe par un minimum.

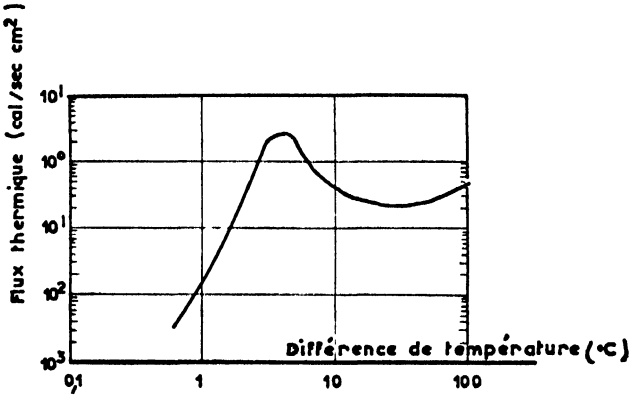


Fig 11. Flux thermique entre une tige de cuivre et l'azote liquide en fonction de l'écart de température (d'après Cowley, Timson et Sawdye)

Les gaz liquéfiés peuvent constituer une technique de congélation industrielle importante dans l'avenir. Cependant, pour procéder à la congélation de paquets de poisson dans l'azote liquide, il convient de limiter les échanges au début. Si, en effet, la couche superficielle est totalement gelée avant que l'eau de la région centrale ne commence à cristalliser, les tensions qui apparaissent dans la région centrale, dues à l'accroissement de volume de la glace, provoquent l'éclatement du paquet.

La *congélation par contact* permet d'assurer une congélation rapide. Cependant, il convient de tenir compte des deux conditions suivantes:

la surface de poisson en contact avec les plaques froides doit être maximale; cette technique convient bien à des paquets ou blocs parallélipédiques qui peuvent être congelés par leur deux plus grandes faces (avec serrage des plateaux). Elle n'est pas satisfaisante s'il s'agit de poissons entiers;

dans le cas des filets emballés avant congélation, il est essentiel d'éliminer les lames d'air existant inévitablement entre les filets et les films de protection.

La chute de température due à ces lames peut être de plusieurs degC.

Les congélateurs à plaques mobiles, grâce au serrage des paquets, permettent de limiter l'importance des lames d'air sur la transmission de la chaleur.

Durée de la congélation

De nombreux auteurs ont cherché à déterminer la durée d'une opération de congélation.

R. Plank a, en particulier, proposé trois types de relations selon que le flux est monodimensionnel, bidimensionnel ou tridimensionnel.

Si on appelle:

α le coefficient d'échange en surface

λ le coefficient de conductivité thermique à l'état congelé

$(\theta - \theta_m)$ la différence moyenne entre la température de congélation et la température du milieu

H la quantité de chaleur à extraire par unité de volume

D l'épaisseur de l'objet à congeler (ou diamètre)

l la largeur

L la longueur avec $L > 1 > D$

le temps "t" est:

flux monodimensionnel:

cas d'une plaque

$$t = \frac{H}{\theta - \theta_m}\left[\frac{D}{2\alpha} + \frac{D^2}{8\lambda}\right]$$

cas d'un cylindre

$$t = \frac{H}{\theta - \theta_m}\left[\frac{D}{4\alpha} + \frac{D^2}{16\lambda}\right]$$

La congélation d'un cylindre est deux fois moins longue que celle d'une plaque.

flux bidimensionnel: cas d'un parallélépipède

$$t = \frac{H}{\theta - \theta_m}\left\{\frac{1}{\alpha}\frac{1.D}{2(1+D)} + \frac{1}{\lambda}\left(\frac{1.D}{16} - \frac{(1-D)^2}{32}\ln\left[\frac{1+D}{1-D}\right]\right)\right\}$$

flux tridimensionnel: cas d'un parallélépipède

$$t = \frac{H}{\theta - \theta_m}\left\{A \cdot \frac{D}{\alpha} + B\frac{D^2}{\lambda}\right\}$$

où A et B sont fonctions de $1/D$ et L/D.

Divers auteurs (Teider, Kazuo Tanaka et Coll, Nagaoka et Coll, etc.) ont établi des formules dérivées de celle de R. Plank. Dans l'ensemble, toutes les relations ainsi établies sont d'un emploi assez difficile d'autant que certains paramètres ne peuvent être pris en considération. Ainsi, en toute rigueur, on ne prend pas en considération les échanges particuliers qui ont lieu dans les angles des paquets. De même, certains paramètres, caractéristiques de la forme des espèces, peuvent modifier sensiblement la durée réelle de la congélation; par exemple, les saumons sont congelés plus rapidement que des flétans de même taille, toutes les autres conditions étant identiques, parce que la cavité abdominale des saumons est plus grande que celle des flétans (F. Soudan *et al.*). L'état d'engraissement peut également constituer un élément variable non négligeable: un muscle gras se congèle plus vite qu'un muscle maigre.

En pratique industrielle, il est important de contrôler directement la vitesse de congélation par la mesure des températures dans les poissons et paquets de filets. En général, la *vitesse moyenne de congélation* est comprise entre 1 et 3 cm/h, selon l'appareillage utilisé.

En règle générale, on estime que l'*opération de congélation est terminée* quand les poissons et paquets de filets sont amenés à la température d'entreposage.

La *fin de la congélation* peut être repérée soit quand la température est au point le plus chaud (centre thermique), soit quand la température moyenne (température d'équilibre atteinte adiabatiquement) est égale à la température d'entreposage.

Dans le premier cas, le séjour d'un chargement dans le congélateur est un peu trop long. De fait, l'excès de séjour est petit. En effet, à la fin de la congélation d'un lot, le flux thermique dans la substance tend à augmenter par suite de l'accroissement de la conductivité thermique (la conductivité thermique de la glace est quatre fois plus grande que celle de l'eau). D'autre part, la puissance thermique à fournir devient faible; la fraction d'eau à congeler est minime; la chaleur massique de la glace est moitié de celle de l'eau liquide.

Dans le second cas, le chargement est sorti de l'appareil de congélation avant que la cristallisation soit complète, à coeur. Or, quand les échanges deviennent moins intenses, la glace a tendance à se former en cristaux plus gros; d'autre part, l'écart entre la température réelle à coeur et la température d'entreposage est d'autant plus grand que l'objet est de plus grandes dimensions, et en particulier qu'il est plus épais. Enfin, il existe une certaine imprécision dans l'équivalence entre la température à coeur et la température d'équilibre; il suffit d'une petite modification des dimensions ou des conditions de congélation pour que le produit soit insuffisamment refroidi.

Pour l'ensemble des raisons résumées ci-dessus, il est préférable de maintenir les poissons et filets en appareil de congélation jusqu'à ce que *la température à cœur soit égale à la température d'entreposage.*

Le sous-refroidissement constitue un volant de sécurité pour les manipulations des lots jusqu'aux chambres frigorifiques.

CONCLUSION

L'étude des phénomènes physiques dont les tissus congelés sont le siège conduit finalement à assimiler cette technique à une déshydratation. Mais à l'inverse des produits secs obtenus par les autres processus, l'eau des produits congelés reste en place prête à assurer la réimbibition dans de très bonnes conditions.

D'autre part, tout abaissement de température ralentit les phénomènes biochimiques selon des lois d'allure exponentielle (règle de Van't Hoff).

L'emploi de basses températures aurait permis d'accroître la durée de conservation des poissons, même si dans les tissus, il n'y avait pas séparation de l'eau par cristallisation.

Enfin, toute manifestation de la vie est annihilée aux températures utilisées pour l'entreposage des denrées congelées: certes, les germes ne sont pas tous tués; leur activité par contre est arrêtée.

Ainsi donc, la physique, la chimie, la biologie reconnaissant l'efficacité des basses températures pour le maintien, pendant plusieurs mois des poissons et filets de poisson dans un état pratiquement identique à celui de l'état frais.

Bibliographie

COWLEY, C W, TIMSON, W J and SAWDYE, J A 1961 Ultra rapid cooling techniques in the freezing of biological materials. *Biodynamica*, p. 5.

DEUTSCHER KÄLTETECHNISCHER VEREIN 1958 *Règles pour machines frigorifiques*, Institut international du froid, Paris, p. 152.

DOWELL, L G and RINFRET, A P 1960 Low temperature forms of ice as studied by X-ray diffraction. *Nature, Lond.*, **188**, 1144–1148.

GAC, A 1966 La congélation des denrées, principes et possibilités. *Revue gén. Froid*, 655–668.

INSTITUT INTERNATIONAL DU FROID 1964 *Recommandations pour la préparation et la distribution des aliments congelés*, 123 pp.

JASON, A C and LONG R A K 1955 The specific heat and thermal conductivity of fish muscle. *Proc. IX Int. Congr. Refrig.*, Paris, **1**, 2161–2169.

KHATCHATUROV, A B 1958 Thermal process during air blast freezing of fish. *Annex 1958–2, Bull. int. Inst. Refrig.*, pp. 365–378.

KUPRIANOFF, J 1964 Fundamental and practical aspects of the freezing of foodstuffs—Aspects théoriques de la lyophilisation. Rey et Coll-Hermann, pp. 497–517.

LENTZ, C P 1961 Thermal conductivity of meats, fats, gelatin cells and ice. *Fd Technol.*, **15**, 243–247.

LUYET, B 1962 Principles governing the stability of the ice phase in frozen aqueous substances. *Annex 1962–1 Bull. int. Inst. Refrig.*, 413–424.

MCADAMS, W H 1961 *Transmission de la Chaleur*, Dunod, Paris, 585 pp.

NAGAOKA, J, TAKAGI, S and HOTANI, S 1955 Experiments on the freezing of fish in air blast freezer. *Proc. IX Int. Congr. Refrig.*, Paris, pp. 4105–4110.

PISKAREV, A 1958 The influence of preliminary storage on the histological structure and hydrophilic properties of fish at freezing. *Annex 1958–2 Bull. int. Inst. Refrig.*, 379–389.

PLANK, R 1965 *L'utilisation du Froid dans les Industries Alimentaires*, Dunod, Paris, pp. 644.

REY, L 1959 *Conservation de la Vie par le Froid*, Hermann, p. 167.

REY, L 1964 Aspects fondamentaux de la surgélation. *Revue gén. Froid*, juillet 1964, 707–711.

SOUDAN, FRANCE, ANQUEZ, M and BÉNÉZIT, A 1965 *La Conservation par le Froid des Poissons, Crustacés et Mollusques*, Baillière et fils, Paris, 514 pp.

TAMMAN, G and BÜCHNER, A 1935 (Voir Rey, 1959.)

TANAKA, K and NISHIMOTO, J Determination of the time
1963 required for contact freezing of whalemeat. *Proc. XI Int. Congr. Refrig.*, Munich, **1**, 415–422.

TCHIGEOV, G B Criterional generalization of experimental
1958 data on the freezing of foods. *Annex. 1958–2 Bull. int. Inst. Refrig.*, 423–428.

TEIDER, V A Determination of freezing time with different
1963 conditions of heat exchange at the body surface. *Proc. XI Int. Congr. Refrig.*, Munich, **3**, 953–956.

WOOLRICH, W R Specific and latent heat of foods in the
1966 freezing zone. *ASHRAE Jl*, 43–47.

Influence of Freezing and Cold Storage on the Submicroscopical Structure of Fish Muscle

by A. Liljemark

Influence of freezing and cold storage on the submicroscopical structure of fish muscle

Studies by electron microscopy have been performed on thin sections of fibres from white muscle of cod (*Gadus morhua*) at different stages *post-mortem*, and from thawed fish after cold storage.

The predominant changes observed in chilled fish seemed to be related to membraneous structures. In frozen and thawed fish there may be, in addition to these changes, varying degrees of disorder similar to those that can be observed at the magnifications of optical microscopy.

However, by careful measurements, no difference was found in the ranges of distances between thick myofilaments in samples from unfrozen cod taken immediately *post-rigor* and those in samples of the same batch of fish, frozen immediately, held in cold storage and thawed after severe toughness, as shown by texture measurements, had appeared.

It is concluded that the increasing toughness during cold storage might be due more to changes within the filaments themselves than to their relations to each other or, possibly, that the embedding procedure used for preparation of the tissues for electron microscopy, though among the best ones known for avoiding shrinkage—might have obscured a closer packing of the filaments after cold storage of the fish.

Influence de la surgélation et de l'entreposage en chambre froide sur la structure submicroscopique du muscle de poisson

On a étudié au microscope électronique des coupes minces de fibres provenant des muscles blancs de morue (*Gadus morhua*) à divers stades *post-mortem*, ainsi que de poisson décongelé après entreposage en chambre froide.

Les principales modifications observées dans le poisson réfrigéré semblent affecter les structures membraneuses. Dans le poisson congelé puis décongelé, ces modifications peuvent en outre s'accompagner de diverses perturbations analogues à celles que permet d'observer le microscope optique.

Toutefois, après des mesures minutieuses aucune différence n'a été constatée dans la gamme des distances entre myofilaments épais provenant d'une part d'échantillons de morue non congelés prélevés immédiatement après la rigidité cadavérique, et d'autre part d'échantillons du même lot de poissons, congelés immédiatement, entreposés en chambre froide et décongelés, après apparition d'une forte coriacité, constatée par des mesures de la texture.

On en conclut que l'accroissement de coriacité durant l'entreposage frigorifique pourrait être liée davantage aux modifications survenant à l'intérieur des filaments eux-mêmes qu'aux rapports entre eux. Peut-être que les procédés employés pour préparer les tissus en vue de leur examen au microscope électronique—bien qu'on n'en connaisse guère de meilleurs pour éviter la réduction de volume—ont masqué un resserrement des filaments après entreposage du poisson en chambre froide.

Influencia de la congelación y del almacenamiento frigorífico en la estructura submicroscópica de la carne de pescado

Sirviéndose del microscopio electrónico se han realizado estudios de secciones de fibras de la carne blanca del bacalao (*Gadus morhua*) en diferentes fases *post-mortem*, y con pescado congelado después de su almacenamiento frigorífico.

Los cambios predominantes observados en el pescado refrigerado parece que tienen relación con las estructuras membranosas. Al parecer, en el pescado congelado y descongelado existen, además de estos cambios, varios grados de desorden parecidos a los que se pueden observar en las amplificaciones que se consiguen con el microscopio óptico.

Sin embargo, con las cuidadosas mediciones efectuadas no se encontraron diferencias en las distancias existentes entre los miofilamentos delgados de las muestras de bacalao no congelado tomadas inmediatamente *post-rigor* y los de las muestras de la misma partida de pescado congelado inmediatamente, mantenido en almacenamiento frigorífico y descongelado después de un intenso endurecimiento, como lo indican las mediciones de la textura.

Se concluye que el creciente endurecimiento durante el almacenamiento frigorífico es posible que se deba más a los cambios ocurridos dentro de los filamentos mismos que a sus relaciones entre sí, o, posiblemente, que el procedimiento de encastrado empleado para la preparación de los tejidos para la microscopia electrónica—aunque figuran entre los mejores que se conocen para evitar el deterioramiento--haya hecho pasar inobservada una mayor aglomeración de los filamentos después del almacenamiento frigorífico del pescado.

WITH the increasing general knowledge of the submicroscopical anatomy of muscle fibres there is a growing interest in attempts to correlate the toughening effect of cold storage on fish muscle with presumed changes in its fine structure. A survey of the freezing of animal tissue covering also histological work, done mainly at the level of optical microscopy, has been given by Love (1966). From their own work on microscopy, including electron micrographs of homogenized fish muscle (Love and Abel, 1966), Love has concluded that "toughness is related to an increased cohesiveness of the myofibrils while softness (in chilled fish) appears to be the result of removing structural material from them" (Love, 1967). Using electron microscopy of thin sections from fresh or thawed fish Partmann (1964) observed interesting structural differences, but he also remarked at that time that material which had been frozen and thawed was more difficult to preserve for microscopy. Tanaka (1965) concluded from his micrographs of thin sections, that toughening in muscle fibres of Alaska pollack (*Theragra chalcogramina*, Pallas) due to frozen storage was correlated with decreased widths of myofibrils and a shorter distance between myofilaments. This laboratory has previously published some electron micrographs on fresh or cold-stored fish together with brief comments (Liljemark, 1964). Further observations will be reported here; firstly, general observations on structural changes due to freezing in fibres from white muscle of cod, and secondly, results from measurements of the distance between thick myofilaments in such fibres.

MATERIAL AND METHODS

Material

Cod (*Gadus morhua*) for this study were caught by trawl off the west coast of Sweden. For the main series of measurements of distances between filaments, muscle samples were taken from the inner part of fillets below the second dorsal fin of 60 to 80-cm cod. Fish for freezing was wrapped in aluminium foil, frozen in air-blast at −40°C (−40°F), stored at the temperatures given and thawed in air at +3°C (37°F). For general observations smaller fish and samples from other parts of the lateral muscle were also used as well as fish that had been plate-frozen. Samples from *pre-rigor* fish were taken immediately after stunning the fish.

Electron microscopy

Thin strips of muscle were fixed at 4°C (38°F) in a 3 per cent solution of glutar aldehyde in 0.1 M phosphate-buffer at pH 7.2, usually overnight, rinsed and trimmed to appropriate size in 0.2 M buffer, post-fixed for 2 h in 1 per cent osmium tetroxide buffered with veronal-acetate, dehydrated in a graded series of ethanol and, with propylene oxide as intermediate, embedded in Epon. Sections were cut with glass knives on a LKB ultra-microtome. They were mounted on uncoated grids and stained with a saturated water solution of uranyl acetate, occasionally followed by staining in lead citrate (Reynolds, 1963). The specimens were examined mainly with a JEM7 electron microscope, but during a preliminary period other different microscopes were used. To obtain reliable comparisons of distances between myofilaments in well-oriented transverse or longitudinal sections the JEM7 microscope was in this case operated at fixed lens currents giving carefully checked magnifications at the order of 5,000 to 17,000 times. On 30 × 40 cm prints with a final magnification of 50,000 times, the average centre-to-centre distance between thick myofilaments was measured in as many areas as possible where straight rows of 10 to 20 filaments could be clearly traced, taking care to avoid directions in which the cutting of the section could have influenced the tightness of the filament packing.

Texture measurements

These were almost entirely taken from an unpublished work on electron microscopy of muscle cell homogenates in which the same fish material was used (Liljemark and Maller, 1966). Adjacent fresh or thawed muscle samples to those taken for measuring filament distance were used. Turbidity measurements on suspensions from these samples were performed according to the cell fragility technique of Love and Mackay (1962) with some minor modifications (slightly different homogenizer, 120 mg sample to 12 ml fluid, 6,000 rev/min checked by stroboscope, see Liljemark, 1964). Values given are, in general, the means of five measurements on each of three fish.

Penetrometer readings were obtained on thawed cross-sections of frozen fish. A 1-cm thick disc had been sawed out across the tail of the fish near the third dorsal fin and trimmed to fit into a metal dish of 6-cm diameter. Immediately after thawing, the resistance of the disc to a 5-mm deep penetration by a metal rod of 5-mm diameter was measured in a sensitive recording strain-gauge masticator (Drake, 1967). Avoiding connective tissue, the rod was lowered into the middle of each of the four concentric muscle bundles of the cross-sectioned tail of the fish and the average peak heights of the recorded strain curves taken as a measure of its firmness or toughness. Previous experience has shown this to be well correlated with the time-temperature history of the frozen fish and preferable to similar measurements on cooked cross-sections or on either raw or cooked length-sections.

RESULTS AND DISCUSSION

General observations

The organization of fibres from the lateral body muscle of cod is, in some respects, intermediate to the models given for frog sartorius muscle (Peachey, 1965; 1966) and for the tropical fish species black mollie [(*Mollienesia* sp.) Franzini-Armstrong and Porter, 1964], both of which have been more thoroughly studied. Sets of thick and thin myofilaments interdigitate more or less according to the state of contraction and form the well-known regions called I-band, A-band and H-zone (figs 1 and 2). In the middle of the I-band the thin filaments are transversally linked together in the Z-line and in the middle of the H-zone the thick filaments are connected in some incompletely known manner in the M-band, often seen as five separate lines. The myofilaments are bathing in the sarcoplasmic fluid and gathered into myofibrils. In cross-section these fibrils are of greatly varying size and shape, from nearly circular in the middle of the fibre to flat, rectangular at the border (fig 3). Between the fibrils, the sarcoplasmic reticulum (s.r.) forms interconnected vesicles with a content that is believed to be separate from the sarcoplasmic fluid in the living animal. At the level of the H-zone the s.r. forms an irregular sac, like a collar around each fibril; at the Z-line two so-called terminal cisternae of the s.r. containing some electron dense material embrace a narrow channel, usually called transverse tubule. These tubules are separate from the s.r. and have in some species been shown to be invaginations of the fibre envelope, the sarcolemma. As in frog sartorius

Fig 1. Length-section of white muscle fibre from pre-rigor *cod. Connections between the terminal cisternae of the sarcoplasmic reticulum and its sac surrounding the middle of the sarcomere (Z-line to Z-line part of fibril).* N, *nucleus;* sl, *sarcolemma;* tc, *terminal cisternae of sarcoplasmic reticulum;* g, *glycogen;* m, *mitochondrion;* p, *pinocytic vesicle;* tt, *transverse tubule*

Fig 2. Length-section from cod frozen immediately post-rigor *and thawed after storage at −20°C (−4°F) for two and a half months*

(Peachey, 1966), this connection has not yet been directly visualized in cod muscle, perhaps because of a changed appearance of the tubules near the sarcolemma. In this region the nuclei and most of the mitochondria are to be found in white muscle fibres. Grains of glycogen are usually abundant here but may also be scattered almost anywhere in the sarcoplasm. The sarcolemma itself is best observed in specimens where two adjacent fibres are embedded together and their interface thus protected against removal of material during preparation (fig 4). It is composed of an ordinary cell membrane innermost (plasmalemma) coated by an amorphous layer of varying thickness (basement membrane) strengthened by varying amounts of collagen fibrils. The outer layers seem to be rather easily split off even during chill storage.

The main changes observed in these structures in fish after death or during ice storage,[1] and those which may (but do not necessarily) occur after freezing, cold storage and thawing, are listed in table 1. Apart from varying degrees of contraction caused by the *rigor* events, the predominant change, as indicated by indirect evidence, is a gradual increase in permeability of all membraneous structures beginning during chilled storage. This is further enhanced by the freezing-thawing procedures, which also may cause the same kind of gross or minor disorder that can be observed at the lower magnifications of optical microscopy (fig 5). The myofilaments are seemingly very well preserved after all treatments. On occasions, such changes which could have been interpreted as breaks in the I-band have been revealed as sarcoplasmic vesicles pushed into the I-band so that the

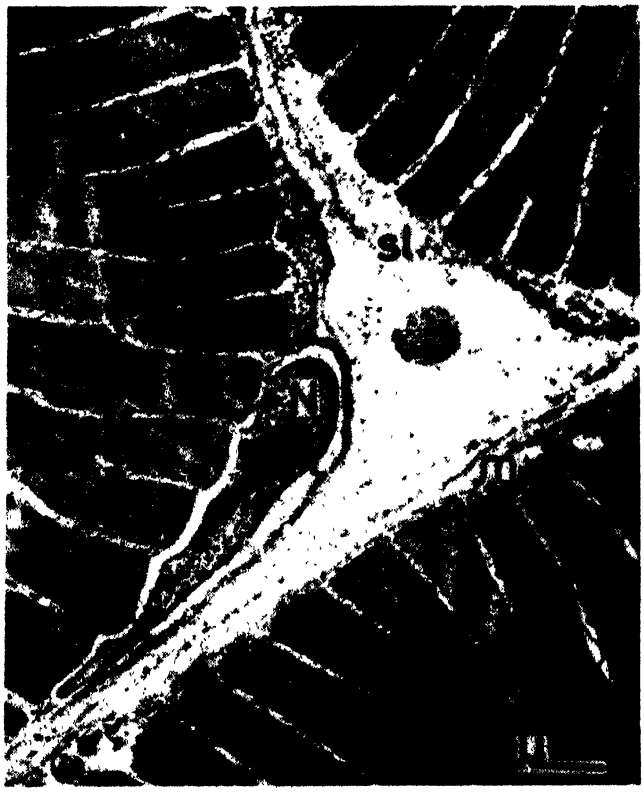


Fig 3. Cross-section from pre-rigor *cod, covering parts of three fibres*

Fig 4. Section from the contact area between two muscle fibres from pre-rigor *cod, nearly transversely cut. The distinction between the outer layer of the sarcolemma and connective tissue is diffuse*

TABLE 1. TYPICAL TRAITS OF VARIOUS STRUCTURES IN WHITE MUSCLE FIBRES OF COD AS SEEN IN THE ELECTRON MICROSCOPE

	Pre-rigor	*Post-rigor*	*Frozen* post-rigor *cold stored and thawed*
Sarcolemma	Composed of plasmalemma + basement membrane + layer of collagen fibrils. Invaginations of plasmalemma, suggesting pinocytosis ("cell-drinking")	Seems to get progressively looser and more or less separates from the fibre. No pinocytic invaginations	Outer layers often disintegrated, plasmalemma often split off from fibre
Fibrils	Rather tightly packed: usually in contact with the sarcoplasmic reticulum between them	Somewhat more separated due to expansion of sarcoplasmic reticulum	May be very tightly packed or separated by large spaces containing fragmentary or precipitated material
Filaments		Well preserved	Well preserved. Transverse links in Z-line seem to be weak, links in M-line seem to be strong
	The tightness of packing varies within almost the same range (see text and table 2)		
Sarcoplasmic reticulum	Vesicles moderately expanded; distinct precipitates in terminal cisternae	Vesicles swollen early *post-rigor*, later on relaxed as if they were passively floating in the medium	As in later stages *post-rigor*; large vesicles seem occasionally to have been disintegrated and transformed into smaller ones
Mitochondria	Usually rather well filled with evenly-spaced cristae. The degree of swelling may vary	Often progressively more shrunken	May be shrunken or swollen (ev. empty)—areas of both types may be found within one mitochondrion (fig 8)
Nuclei		Often progressively more shrunken	Often progressively more shrunken
Membranes in general	May seem to be composed of subunits already in *pre-rigor* samples, which is why it is difficult to ascertain by *direct* observation if they have turned more permeable, unless they are found to be discontinuous as sometimes occurs in thawed samples		

Fig 5(a). Cross-section from muscle fibre of unfrozen cod immediately post-rigor

Fig 5(b). Cross-section from muscle fibre of cod frozen post-rigor *held for two months at −20°C (−4°F) and thawed*

filaments have been merely moved apart without breaking (fig 2).

Since variation in section thickness and other factors may influence the appearance of the image, a closer examination was needed to find out if the filaments were more tightly packed after cold storage and thawing. The most fruitful approach seemed to be to study the thick filaments as they keep their places in the hexagonal pattern more consistently than the thin ones.

Centre-to-centre distance between thick filaments

Length-sections. In an attempt to use already available electron micrographs from well-oriented sections about 60 prints from 30 fresh or frozen and thawed specimens were carefully studied with respect to the width of different bands (A, I, H, M), etc., and with respect to the distance between thick filaments in the middle of the M-band, where the distance could be most accurately measured. From the variation in A-band width it was soon realized, however, that the degrees of magnification were not strictly comparable in these micrographs from different electron microscopes. The average A-band width of 1.4 μ was found from a new series of micrographs at constant and carefully calibrated magnification and used for correction of the previous measurements. Thus, the average distance between the centres of the thick filaments was found to be, in Ångstroms (ranges within brackets): *pre-rigor* 349 (285–395), *post-rigor* 346 (300–425) and cold-stored and thawed 355 (260–465). This did not seem very convincing and the result was thought to have been influenced by differences in thickness and in the orientation of the longitudinal sections in relation to the transversally hexagonal array (fig 6).

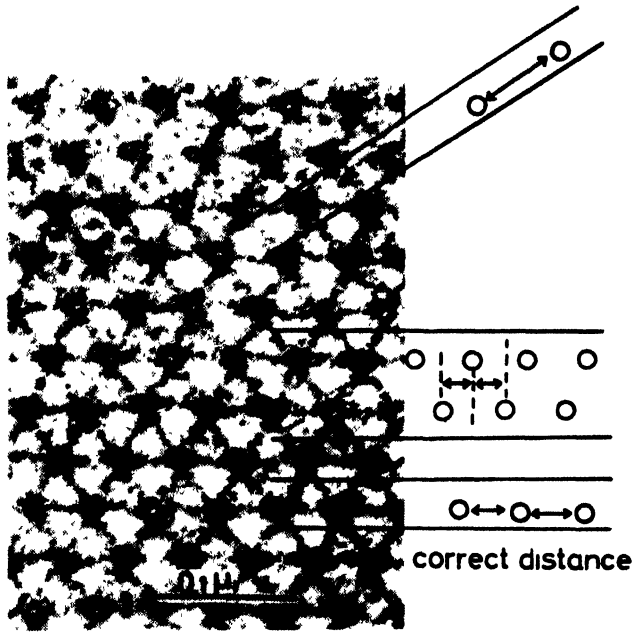


Fig 6. Cross-section of thick myofilaments in M-line showing links between them. How the cutting of length-sections may influence the evaluation of distances is demonstrated

Cross-sections. As projection errors could be avoided in transverse sections, these were measured in those A-band regions where thick and thin myofilaments overlap, taking care to select the shortest distance between thick filaments according to fig 6.

From the values in table 2 it is seen that the mean distance may decrease slightly when the muscle goes through *rigor*, but that no further decrease was found in fish frozen immediately *post-rigor* and thawed after cold storage at different temperatures for such a period that texture measurements showed them to be definitely tough (fig 7). Both before freezing and after storage and thawing, the distance varied within a rather wide range, in general 330–440 Å. Before *rigor*, the shortest distance found was 365 Å. After cold storage some shorter distances down to 265 Å were found, but on the other hand some tough samples showed the same range as *pre-rigor* specimens.

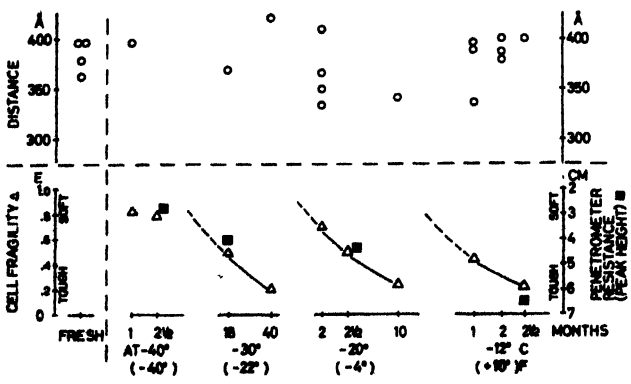


Fig 7. Average centre-to-centre distance between thick filaments in muscle samples from cod, kept for three days in ice or frozen at this stage, cold stored and thawed, combined with results from texture measurements on the same fish (means of at least 15 measurements)

TABLE 2. CENTRE-TO-CENTRE DISTANCE BETWEEN THICK FILAMENTS IN OVERLAPPING REGIONS OF A-BANDS, AS MEASURED IN CROSS-SECTIONS OF DIFFERENT SPECIMENS FROM WHITE MUSCLE OF COD

State of fish	*No. of prints from different areas*	*Range*	*Mean distance*
UNFROZEN			
Pre-rigor	2	395–445	433
	9	395–445	422
	3	395–445	419
	3	365–395	382
			Mean 414
Post-rigor 3 days in ice	3	354–440	397
	2	380–415	397
	2	355–415	377
	2	330–395	631
			383
Post-rigor			
7 days in ice	2	330–400	368
12 days in ice	10	360–440	399
14 days in ice	1	355–415	384
19 days in ice	2	330–400	360
			378
FROZEN AFTER THREE DAYS IN ICE COLD STORED AND THAWED			
Not tough			
1 month at −40°C (−40°F)	7	330–440	394
2 months at −20°C (−4°F)	3	285–400	351
	2	305–360	335
	2	400–440	410
	2	360–365	363
			370
Intermediate			
18 months at −30°C (−22°F)	3	330–415	366
1 month at −12°C (+10°F)	2	330–360	341
	4	330–440	397
	4	330–440	387
			373
Tough			
40 months at −30°C (−22°F)	2	400–442	421
10 months at −20°C (−4°F)	3	265–395	339
2 months at −12°C (+10°F)	6	385–445	399
	5	365–425	388
	1	365–395	382
2½ months at −12°C (+10°F)	2	365–445	401
			388

CONCLUSIONS

Indirect evidence in this study has indicated that the membranes have already become more permeable *post-mortem* in the unfrozen state and more so by mere freezing and thawing. This has been proven biochemically in works such as that of Dawson (1966) on the efflux of enzymes from chicken muscle. It therefore seems plausible that the diminishing water-holding capacity during prolonged cold storage is less influenced by damage to the fibre envelope than by changes in the contractile protein structures of the muscle fibre. Such changes of the myofibrils, also resulting in toughness, were believed to be reflected in a shorter distance between them in the fibrils.

The number of observations on that aspect made in this study may be small but they nevertheless point to the following conclusions:

(1) Either a closer packing of the thick filaments is not a prerequisite for toughening of cod muscle fibres during cold storage; or

Fig 8. Mitochondria with both compressed and empty areas. From thawed cod stored for six months at −30°C (−22°F)

(2) The technique used for preparation of the specimens for the electron microscopy may change the tissue so that eventual differences in packing are concealed.

If the first statement is correct, the cause of toughening is probably to be found within the thick and the thin filaments themselves or in their relation to each other, irrespective of the distances between them. More about such polymerization or cross-linking may eventually be revealed by further electron microscopy at high resolution.

If the second statement is correct—and this might be possible although the technique used is known to give good preservation—other means of preparation for electron microscopy of non-macerated muscle fibres should be applied and combined with methods for analysing the organization of unfixed muscle fibres.

Both these ways will be tried in future investigations.

Acknowledgments

The skilled technical assistance of Miss Marieanne Andersson, Mrs. Margit Fredrikson and Mrs. Gunnel Schallin is gratefully acknowledged. The work has been supported by a grant from the Swedish Foundation for Scientific Research and Industrial Development for the purchase of an electron microscope.

References

DAWSON, D M *Biochim. biophys. Acta*, **113**, 144.
1966

DRAKE, B (Manuscript)
1967

FRANZINI-ARMSTRONG, CLARA, and PORTER, K *J. Cell Biol.*
1964 **22**, 675.

LILJEMARK, A *SIK-Rapport*, No. 156, Göteborg, Svenska
1964 Institutet för Konserveringsforskning. (In Swedish, mimeo.)

LILJEMARK, A and MALLER, M Svenska Institutet för
1966 Konserveringsforskning, Göteborg. (MS.)

LOVE, R M In *Cryobiology*, ed. H. T. Meryman, London,
1966 p. 317.

LOVE, R M Paper presented at the Symposium on the
1967 Rheology and Texture of Foodstuffs, organized by Society of Chemical Industry and the British Society of Rheology.

LOVE, R M and ABEL, G *J. Fd Technol.*, **1**, 323.
1966

LOVE, R M and MACKAY, ELEANOR *J. Sci. Fd Agric.*, **13**, 200.
1962

PARTMANN, W *Kältetechnik*, **16**, 341.
1964

PEACHEY, L D *J. Cell Biol.*, **25**(3), part 2, 209.
1965

PEACHEY, L D *Annals of the New York Academy of Science*,
1966 **137**, Art. 2, 1025.

REYNOLDS, E S *J. Cell Biol.*, **17**, 208.
1963

TANAKA, T In *The Technology of Fish Utilisation*, ed.
1965 R. Kreuzer, Fishing News (Books) Ltd., London, p. 121.

DISCUSSION

Connell and Howgate (U.K.): For a number of years past we have been carrying out studies on the ultrastructure of processed cod muscle which closely parallel those by Mr. Liljemark. Our studies have been briefly reported in the Annual Reports of Torry Research Station for the years 1963, 1964 and 1965, but we felt it would be appropriate to give a more extended account.

Our methods are very similar to those used by Liljemark. Cod muscle fibres taken from near the backbone at the level of the first dorsal fin, were fixed for 2 h at 2°C (35.6°F) in 2.5 per cent glutar aldehyde in 0.1 M phosphate pH 7.0. They were rinsed in isotonic sucrose, post-fixed in Palade's osmium tetroxide fixative for 2–4 h at 2°C (35.6°F), dehydrated in ethanol and embedded in Epon. Silver-coloured sections (ca. 500–600 Å thick) were cut and observed in a Siemens Elmiskop I microscope. Photographs of the sections were taken at an instrumental magnification of 40,000 and prints made of these photographs at ×2.5 making a total magnification of 100,000.

For measurements of interfilament distances in transverse sections, fields usually showing the H zone were chosen. The spacing was measured along the three major axes of the hexagon formed by the thick filaments. If the section is cut normal to the axis of the fibre the three measurements will be

equal. However, in our case, this was not always so, and to correct for obliqueness the following was used:

$$D = \tfrac{10}{3}\,[S_2 - \sqrt{6S_4 - 2S_2^2}]$$

where

$$S_2 = d_1^2 + d_2^2 + d_3^2$$

$$S_4 = d_1^4 + d_2^4 + d_3^4$$

d_1, d_2, d_3 = length in millimetres of 10 spaces measured along the major axes of the hexagon

D = true interfilament spacing in Å.

Our observations on the detailed ultra structure of *pre-rigor* cod agree with those of Liljemark with the exception that minimum sarcomere and A-band lengths of 1.37 μ and 1.21 μ were obtained. As far as the A-band distance is concerned, this is somewhat smaller than that quoted by Liljemark. In addition, as shown later, slightly smaller interfilament distances are found by us.

Observations on *post-rigor* muscle included some on fish which had been held up to 17 days in melting ice. The general features of the changes in structure accord well with those recorded by Liljemark in his table 1. In particular, we would like to draw attention to the retention of contrast and distinctness in the filament structures at all stages of icing, findings which are at variance with those of Partmann on carp muscle [*Kältetechnik*, **16**, 34 (1964)]. In cod which has been iced for 17 days considerable degradation of the sarcoplasmic reticulum to a granular material occurs. Measurements of interfilament distances (below) have been confined to cod stored in ice for two to three days, but definitely support Liljemark's suggestion that there is a decrease of this distance on passing through *rigor mortis*. Such a decrease is presumably one manifestation of the general syneresis-like change in the muscle with accompanies *rigor* and which results in fluid transferring from the myofibrils to the interfibrillar and intercellular spaces.

Observations on frozen stored cod have been made on two days iced samples stored for up to five months at −14°C (7°F), conditions which lead to the development of considerable toughness, and for nine months at −29°C (−20°F), a condition under which there is little change in toughness. Again our general findings confirm those of Liljemark recorded in his table 1. An important exception is our finding that the interfibrillar space always seems to be less in the frozen stored material at −14°C (7°F) than in the unfrozen material. In fact there is an obvious (but not yet measured) progressive diminution in interfibrillar space as storage proceeds, until in the five-month sample much of the space has disappeared. At the border of the touching fibrils is a band of more intensely electron dense material as though the fibrils had coalesced and cemented together at the surfaces where they are in contact with one another. This kind of progressive adhesion or aggregation of the fibrils is clearly the reason why it is more difficult in badly frozen stored cod to separate the fibrils from one another when the muscle is teased or blended. A change of this kind may of itself be one of the contributing causes for the development of sensorily-detectable firmness. Presumably this reduction in interfibrillar distance is, in the early stages at least, the result of changes in the sarcoplasmic reticulum (or what remains of it in *post-rigor* muscle) such that the fibrils are even more firmly and closely bonded together.

Although earlier measurements had indicated that the interfilament distance decreased on frozen storage at −14°C (7°F), a larger range of observations has failed to confirm this. It has been found that there is a fairly large variation in the interfilament distance of samples treated identically, but the results (below) show that there is no significant systematic change in interfilament distance on frozen storage at −14°C (7°F). It is possible that further observations will reveal a significant diminution on storage, but at the moment we agree with Liljemark that a marked toughening of cod muscle can occur without a presently measurable change in interfilament distance. It is interesting in this connection that a sample of cod muscle which had suffered freezer burn, and was thus very tough to eat, gave an interfilament distance of 261 Å which is significantly lower than any of the other samples examined.

TABLE 3. CENTRE-TO-CENTRE DISTANCES BETWEEN THE THICK FILAMENTS IN TRANSVERSE SECTIONS OF COD MUSCLE

Treatment	*Fish (No.)*	*Mean interfilament distance (Å)*	*Prints measured (No.)*	*95 per cent confidence limit of mean (Å)*
Pre-rigor		405	23	6
		402	7	11
		356	9	10
		377	7	12
Post-rigor		378	2	23
(2 days iced)		326	9	10
		329	8	11
Post-rigor (2 days iced)				
1 month at −14°C		336	6	13
2 months at −14°C		373	5	14
3 months at −14°C		341	5	14
5 months at −14°C		357	5	14
9 months at −29°C		374	4	16
Weighted mean distances for separate treatments				
Pre-rigor		392		
Post-rigor		332		
Stored at −14°C		352		

Liljemark (Sweden): Connell seems to agree with me on all main points. I would like to add, only, that even slight differences in the technique used should be considered very carefully when results from this kind of work are compared.

Connell (U.K.): There has been a question in regard to the fact that cross-linkages are not visible in Liljemark's electronmicrograph. Those of us who have studied the changes in proteins during frozen storage have a very strong conviction that toughening is attributable to formation of additional cross-links between the myofibrillar proteins, but this kind of linkage is unlikely to be observed in electron micrographs such as we can obtain at this moment. Cross-links, as we envisage them, are at the intermolecular level and presumably take place between the so-called cross-bridges which occur between the thick and thin filaments of the muscle.

Freezing of Shellfish

by P. Hansen and J. Aagaard

Freezing of shellfish

This review paper describes the freezing of shellfish and the various factors which influence the manufacture and quality of the frozen shellfish. The paper is divided into two parts: (1) Freezing of crustacea like crabs, lobsters, shrimps and prawns; and (2) Freezing of molluscs like cephalopods (squids, cuttlefish), gastropods (abalones, winkles) and pelecypods (oysters, scallops, mussels clams).

Freezing of the various types of shellfish includes the following common features:

(1) The freshness state of the shellfish to be frozen is very important. Several of the species even have to be processed from the live state.

(2) The shellfish may be frozen either raw or after heat treatment. Strict hygiene is necessary in both cases, but special care should be taken, when the shellfish are to be frozen after cooking and thus will not be heat-treated between thawing and consumption. Excessive boiling prior to freezing should normally be avoided for reasons of quality.

(3) Shellfish may be frozen either shells-on or shucked (peeled). Removal of the shells prior to freezing is normally performed, when edible content is small compared with the live weight of the shellfish. This is especially the case with many molluscs. When shellfish are frozen shells-on, special precautions may be necessary to facilitate the later removal of the shells.

(4) As regards the influence of freezing time and temperature during cold storage the recommendations known from frozen fish apply to shellfish too.

(5) The frozen shellfish are very susceptible to desiccation and oxidation during cold storage, and much care should be taken to protect the meat against drying up. This is also necessary, when the shellfish are frozen shells-on, because the shells are not able to render sufficient protection themselves.

Congélation des crustacés et mollusques

La présente étude traite de la congélation des crustacés et des mollusques et des divers facteurs affectant la fabrication et la qualité des produits finis. Elle est divisée en deux parties: (1) congélation des crustacés: crabes, homards, crevettes; (2) congélation des mollusques: Céphalopodes (calmars, seiches), Gastéropodes (ormeaux, bigorneaux) et Pélécypodes (huîtres, pétoncles, moules, clams).

La congélation des divers types de crustacés ou mollusques présente les caractéristiques communes suivantes:

(1) L'état de fraîcheur de l'animal à congeler est extrêmement important. Certaines espèces doivent même être congelées vivantes.

(2) L'animal peut être congelé soit cru soit après traitement à la chaleur. Dans les deux cas, l'hygiène doit être rigoureuse, mais des précautions particulières doivent être prises lorsque l'animal est congelé après cuisson, et qu'il n'y aura donc pas d'application de chaleur entre décongélation et consommation. Pour préserver la qualité, il faut normalement éviter de trop prolonger la cuisson précédant la congélation.

(3) Les crustacés ou mollusques peuvent être congelés soit dans leur carapace ou coquille soit décortiqués ou écaillés. Lorsque la partie comestible est petite par rapport au poids vif de l'animal, on retire normalement les carapaces ou coquilles avant la congélation. C'est notamment le cas pour nombre de mollusques. Quand les animaux sont congelés dans leur carapace ou coquille, il peut être nécessaire de prendre des précautions particulières pour faciliter le décorticage ou décoquillage ultérieur.

(4) Pour ce qui est de l'influence de la durée de congélation et de la température d'entreposage frigorifique, les recommandations valables pour la congélation du poisson s'appliquent également aux crustacés et mollusques.

(5) Les crustacés et mollusques congelés craignent beaucoup la dessiccation et l'oxydation durant l'entreposage en chambre froide, et il faut veiller soigneusement à protéger leur chair du dessèchement. Cela vaut également pour les animaux non décortiqués ou écaillés, les carapaces ou coquilles ne fournissant pas par elles-mêmes une protection suffisante.

La congelación de mariscos

En este trabajo se describe la congelación de mariscos y los distintos factores que influyen en la fabricación y en la calidad de los mariscos congelados. El estudio se divide en dos partes: (1) congelación de crustáceos tales como cangrejos, langostas, camarones y langostinos; (2) congelación de moluscos tales como cefalópodos (calamares, sepias), gasterópodos (orejas de mar, bigaros), y pelecípodos (ostras, vieiras, mejillones, almejas).

La congelación de los distintos tipos de mariscos incluye las siguientes características comunes:

(1) El estado de frescura de los mariscos que hay que congelar es muy importante. Algunas de las especies incluso tienen que elaborarse cuando están vivas.

(2) Los mariscos se pueden congelar crudos o después de tratarlos por el calor. En ambos casos es necesaria una estricta higiene pero se debe tener un cuidado especial cuando los mariscos se van a congelar después de cocinarlos y por esto no se deben tratar por el calor en la fase comprendida entre la descongelación y el consumo. Por razones de calidad normalmente debe evitarse hervirlos demasiado antes de efectuar la congelación.

(3) Los mariscos se puedon congelar con la concha o caparazón o sin ellos. Por lo general, la concha se quita antes de la congelación cuando el contenido comestible del marisco es pequeño comparado con su peso en vivo. Esto es especialmente lo que ocurre con muchos moluscos. Cuando los mariscos se congelan con la concha o caparazón es necesario adoptar precauciones especiales para poder quitárselos posteriormente.

(4) Por lo que se refiere a la influencia del tiempo de la congelación y la temperatura del almacenamiento en frío, se aplican también a los mariscos las recomendaciones que ya se conocen sobre el pescado congelado.

(5) Los mariscos congelados se desecan y oxidan con facilidad durante su almacenamiento frigorífico, debiéndose tener mucho cuidado en proteger la carne para evitar que se seque. Esto es igualmente necesario cuando los mariscos se congelan con la concha, ya que ésta no constituye protección suficiente.

CRUSTACEA have been fished in fresh waters and along the seashore since ancient times. They are found in both cold and warm waters. Many thousand different species of crustacea are known, but few of them are utilized commercially. The largest individuals caught weighed more than 10 kg. The smallest crustacea measure less than 1 mm in length. In the present commercial fishing only larger species like crabs, lobsters and shrimps are taken. World landings of crustacea reached a total of 1.18 million t in 1965. Marine species included:

Crabs	312,000 t
Lobsters	120,000 t
Shrimps and prawns	637,000 t

These figures were reached after gradual increases of catches in recent years due mainly to the extension of fishing efforts to greater areas and deeper waters. World resources of the main group, shrimps and prawns, has been reviewed at an FAO conference in 1967. The conference dealt with both exploitation of wild resources and culture of shrimps and prawns.

Exploratory fishing for small pelagic crustacea (*Euphausia superba*), the so-called krill, is now reported to take place in the Antarctic and along the Norwegian coast. This may mark the beginning of harvesting of one of the greatest resources of food protein available in the sea.

At present crustacea are marketed live, fresh or processed by drying, canning or freezing. Crustacea are highly perishable, and processors have to apply complicated modern techniques in order to preserve the high gastronomical qualities through storage and transportation to consumer markets. For some species, processing by freezing is not considered satisfactory and the production is, therefore, of minor importance. For other species, mainly lobsters, shrimps and prawns, the trend is towards increased use of freezing, which preserves the eating quality better than drying or canning.

Crustacea may be frozen in different forms, the simplest being the frozen whole raw animal. Processing to frozen cooked peeled meat involves the largest number of operations, the sequence of which may vary according to circumstances, species and the type of finished product. Before going into details of processing operations some common features of technological importance will be considered.

Biological and anatomical features

Commercial species of lobsters, shrimps, prawns and crabs belong to the decapods or 10-footed crustacea. Appendages for walking, swimming and grasping are differently developed. From the anatomical differences follow differences of type and yield of edible parts, which are normally the following:

True lobsters: tail meat and claw meat
Spiny lobsters: tail meat
Shrimps and prawns: tail meat
Crabs: leg meat and body meat

In some sea fisheries the inedible parts of the crustacea are discarded soon after catch in order to improve the storage life and reduce the bulk of the catch.

The crustacean exoskeleton consists of a chitin-protein structure secreted over the whole body surface by the epidermis. Parts of the exoskeleton are usually stiffened and hardened by the deposition of calcium salts. An important part of crustacean physiology is the molt process, which consists in a softening or dissolution of the inner part of the exoskeleton freeing it from the epidermis, and in the formation of a new exoskeleton. Expansion of body size takes place only within a short period after molt while the new exoskeleton is still thin and elastic. Growth results from a copious intake of water, which will increase the volume of body fluids. At this time crustacea meats tend to be watery and poor in texture.

Soft-shell crabs are crabs, which are removed from the water soon after shedding of the hard shell and before the new shell is too hard for consumption (Dassow, 1963). This is an example of the practical utilization of the natural molt process. In most other cases crustacean processing involves the manual or mechanical peeling of the shell or exoskeleton from the meat at some stage before consumption.

In the natural molt process an alkaline molting fluid appears to be active in freeing the shell from the epidermis (Dennell, 1960). When manual or mechanical peeling are part of the processing, special procedures may be involved in order to free the meat from the shell. The deep-water shrimp, *Pandalus borealis*, cannot be peeled raw immediately after catching and is prepared for industrial peeling either by holding in wet ice for two to three days or by pre-cooking or by combinations of these two procedures.

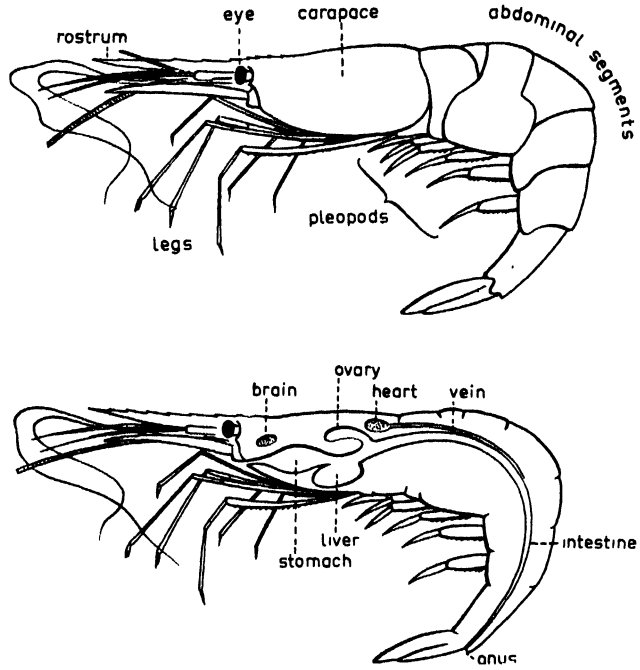


Fig 1. External and internal features of the deep-sea shrimp

The development of efficient and rapid peeling techniques is of special importance in the utilization of small shrimp and other crustacea which cannot bear the cost of the traditional manual peeling.

During the intermolt stage the volume of body fluid varies between 10 and 50 per cent of the body weight (Maynard, 1960). In maritime crustacea the ionic strength of body fluids is about the same as in the surrounding sea-water. This would normally give a freezing point of the raw meat of about −2°C (28°F) (Robertson, 1960). The fluid also contains sugars, lipids, ammonia, amino acids and proteins. The oxygen-carrying pigment in decapod crustacean blood is a copper-protein compound called haemocyanin which occurs free in the blood outside the blood cells. As the circulatory system is open all tissues are generally perfused with the copper compound. One may suspect that under certain conditions the copper content may lead to discolouration and loss of delicacy during processing and storage of crustacea products. Treatment with antioxidants or metal-chelating agents has been suggested in order to minimize oxidative degradations (Anon., 1955; Dassow, 1963; Faulkner and Watts, 1955).

Haemocyanin of crustacea blood is colourless in the reduced form and blue in the oxygenated form (Goodwin, 1960). Blue discolouration of processed crab meat, which

is believed to be due to oxidized copper compounds, can be minimized by removal of blood from the meats. This is done either by bleeding of the live crab (Farber, 1953) or by the fractional cooking method suggested by Osakabe (1961).

Other pigments of crustacea are carotenoids and melanins, which may also influence the result of processing.

The most important carotenoid in crustacea is astaxanthin, which occurs unesterified, esterified or conjugated with proteins. The shells of *Homarus gammarus* contain a blue astaxanthin-protein complex, which turns red on heating. This colour reaction is typical of some shallow-water crustaceans. Deep-sea crustaceans are generally vivid red and do not change colour to any great extent in cooking (Dennell, 1960). If crustacean meats are cold-stored without protection against surface drying and oxidation the red colour may gradually change to orange or yellow (Dyer and Horne, 1953; Montgomery, 1966).

Melanins are chemically ill-defined pigments, which are probably polymerized indole quinones formed by the action of the enzyme tyrosinase on aromatic amino acids (Goodwin, 1960). A discolouration of shells and meat called "black spot", which may occur in prolonged chilled or frozen storage of raw crustacea appears to be associated with enzymatic formation of melanins. "Black spot" may be inhibited by dipping the raw crustacea in diluted solutions of sodium bisulphite before storage (Bailey and Fieger, 1954).

The stomach of live crustacea may contain dark or black fluids. If the crustacea are cooked whole the stomach wall may break and the dark fluid may then flow out and discolour other body tissues and impart a bitter taste to them. According to a procedure recommended in Norway for the processing of live crabs the stomach should either be removed or washed internally by a water current before cooking.

Type of raw material for processing

Some species of crustacea may be stored alive for some time after catching. Marine species of this kind are often stored alive in sea-water or moist air until the time of butchering or cooking. They are usually cooked before *rigor mortis*. This gives lobster and shrimp tails a characteristic shape, which may be required by the trade (Anderson, 1956). The yield of cooked meat is high, and the meat is firm and sometimes more or less tough when the crustacea are cooked alive or before *rigor*.

Species which cannot be stored alive are sometimes cooked immediately after catching in order to obtain the above described characteristics of the cooked meats. They may then be stored, chilled or frozen until further processing can be undertaken. More often, however, crustacea of these species are stored raw, either chilled or frozen, until cooking and other processing can take place. These conditions prevail mainly in the shrimp industry, which may use the following main types of raw materials:

Cooked chilled shrimp or shrimp tails in the shell
Cooked thawed shrimp or shrimp tails in the shell
Raw chilled shrimp or shrimp tails in the shell
Raw thawed shrimp or shrimp tails in the shell

With the deep-sea shrimp, it has been found that the advantage of a maximum yield of cooked meat is obtained only if the shrimp is cooked within 3 h or less after catching. It has not been possible to avoid a somewhat tough texture of the cooked meat resulting from this procedure (Anon., 1966).

Holding raw non-frozen crustacea beyond one day of catching leads to increasing loss of yield and quality. Control of the storage temperature is important, and efficient ice or ice-water chilling should be carried out immediately after catching. An investigation of the weight loss in cooking of Norway lobsters (*Nephrops norvegicus*) shows the effect of holding time and temperature. The lobsters were landed in a Belgian port less than 36 h after catching. One lot cooked immediately lost 22.5 per cent in weight. Cooking after a further 8 h holding at 20°C (68°F) gave 25 per cent weight loss. Cooking after five days of extra storage in ice gave 28 per cent weight loss (Hovart and Vyncke, 1964).

Bulk freezing of whole crustacea for later processing is increasing, although procedures available are not always fully satisfactory. If whole raw crabs or true lobsters are frozen and stored, difficulties are encountered in peeling subsequent to thawing and cooking (Dassow, 1963). The normal procedure, therefore, includes a heat treatment of the whole crustacea prior to freezing. Crabs are usually fully cooked, while lobsters may be cooked fully or partially. In the latter case the aim is to coagulate and break the tissues connecting shell and meat while leaving the interior meat raw. A study on Maine lobsters (*Homarus americanus*) has shown that heating for 70 s. in a liquid at 90°C (194°F) is sufficient to allow easy removal of meat from the shell after subsequent freezing, cold storage, thawing and normal cooking. The meat remained near the raw state after the initial partial heating (Getchell and Highlands, 1957). The partially-cooked lobster appeared to retain quality longer than fully-cooked lobster in subsequent frozen storage. Spiny or rock lobsters may be frozen raw or cooked in the shell without giving difficulties in the subsequent picking of cooked meat from the shell (Anon., 1952). The flavour was good after nine months' storage at −21°C (−6°F), but the meat, which had been stored after cooking, was relatively tough and stringy.

The crayfish (*Jasus lalandi*) appears to lose quality if frozen raw in the shell for some weeks prior to cooking and renewed freezing and cold storage (Anderson, 1956). The poor results may be due to an unsatisfactory technique in the raw material thawing, which is reported to have lasted 16 h.

Danish studies on the bulk freezing and cold storage of glazed shrimp in the shell have shown that cooking prior to freezing retains the red colour better than cooking after thawing. Whole shrimp frozen raw, however, are more easily peeled after cooking and have a better flavour and texture (Aagaard, 1965). Shrimp meats of the latter type could be refrozen without any significant loss of quality.

In American studies (Dassow, 1954) bulk freezing in air or brine of whole raw penaeid shrimp within 2 h after being caught has been compared with the normal ice packing for three days prior to processing. Both procedures of freezing at sea immediately after catching

resulted in a high quality product more nearly approaching the absolutely fresh state than the iced shrimp. Shrimp frozen at sea were superior because of the complete absence of black-spot discolouration. It was found that for refreezing, only the use of absolutely fresh shrimp and prompt handling during freezing, thawing and refreezing will give the best results.

King crab legs, which had been butchered, cooked and frozen on board on the day of catch, could be stored at −18°C (0°F) for one year when packed hermetically in tin containers and for nine months when packed in cellophane or fibre board containers (Heerdt and Dassow, 1952). Refreezing meat from cooked crab, which had been stored in the shell for one month, gave an undesirable tough product after four months' cold storage.

Cooked king crab meat is usually bulk-frozen in large blocks (Dassow, 1963). After freezing, the block is glazed and shipped for later sawing into consumer-size blocks. This procedure eliminates the need of thawing and refreezing.

Cooking

Cooking may be applied as a part of the industrial processing or as a household operation prior to consumption. The cooking is in both cases an important part of the total procedure. The cooking time and temperature should depend on the size and species of crustacea. Small shrimps may be cooked at 90° to 100°C (194° to 212°F) for 2 to 5 min, crabs and lobsters for 5 to 20 min at the same temperature. The cooking consolidates the meat and brings about the typical crustacea flavour. Some meat juices are lost in cooking, which always results in a loss of meat weight. The meat of the deep-sea shrimp may be reduced to about half the weight in the normal heat treatment.

Instructions for household cooking often require that the crustacea are afterwards left to cool immersed in the cooking brine. In industrial cooking, the crustacea are often left to cool in the air. There are indications that slow air cooling may cause some oxidation and loss of colour and eating quality. The prompt chilling of the cooked meat in cold water may be important in order to minimize oxidative degradation and breakage of the meat (Dassow, 1963).

In the industry, the crustacea may be cooked in live steam or in boiling water or brine, which may include herbs and spices as flavouring agents. Steam cooking is preferred for Australian crabs, because with this method further batches of crabs do not become contaminated with the accumulated residues in the cooking tank. It is also claimed that steam cooking gives better colour retention (Montgomery, 1966). In some other industries, however, the trend is now towards cooking in water or brine, which is believed to give a more uniform cooking effect than steam cooking. The effect of salt in the water cooking of shrimp has been studied. Non-salted meats were found to keep better than salted meats in subsequent cold storage if the meats were packed loosely in cellophane bags (Anon., 1961b). When the meats were vacuum-packed in airtight plastic bags, however, it made no difference whether the meats were salted in cooking or not.

Prior to freezing, cooked meats are sometimes dipped or washed in brine containing salt and citric acid.

Sanitation and temperature control

It is extremely important to observe strict sanitary practices and temperature control in all handling, storage and processing of crustacea. Owing to the small size and the large surface, crustacea are very liable to pick up dirt and bacteria, which will lead to off-flavours, discolouration and rapid deterioration. For sanitary reasons aluminium or plastic containers should be preferred to wooden boxes in the bulk handling of raw materials. Catches should be chilled rapidly by thorough mixing with new clean ice or ice water. Bulk freezing of catches should take place as soon as possible after catching. During thawing the crustacea should only for short periods be subjected to temperatures above the freezing point.

The above-mentioned cooking procedures will kill viable micro-organisms but not the spores of Bacillus and Clostridium. Refrigeration of the cooked meat and good sanitation are very important, especially if the cooked meat is given no further heat treatment prior to consumption. The subsequent freezing and cold storage will not eliminate harmful micro-organisms, which may have developed from surviving spores or picked up during the peeling and packing operations.

Peeling involves special dangers of contamination due to the large meat surfaces exposed for some time to the hands of many persons or to the surfaces of complicated machinery. It is, therefore, advisable to wash the peeled meats thoroughly in clean water.

The processing line should not have metal surfaces which may give off traces of catalytic metals such as iron or copper.

Packing

According to the species and the processing involved crustacea may be packed for freezing in the following main forms:

Form packed	*In shell*	*Peeled*
Raw	Shrimp	Shrimp, lobster
Partially cooked	Lobster	
Completely cooked	Shrimp, lobster, crab	Shrimp, lobster, crab

Some principles of freezing crustacea in the shell have been treated above. Crustacea in the shell are packed for cold storage in wooden boxes, waxboard or cardboard containers or tins. Cardboard cartons have been found to have several advantages over the wooden cases, in which frozen rock lobster tails have previously been packed. The cardboard gives faster cooling and better protection against moisture loss (Anon., 1958). Completely moisture-proof packing materials prevent weight loss from the package but not from the crustacea in the shell, which cannot easily be tightly packed and, therefore, leave room for evaporation inside the package and for ice condensation on the inside of the package. Glazing after freezing but prior to the closure of the package is often recommended in order to minimize desiccation of the packed frozen crustacea.

Peeled meat is sometimes frozen in tins or waxboard cartons. Careful packaging to avoid air spaces within the package is essential to attain good keeping qualities of

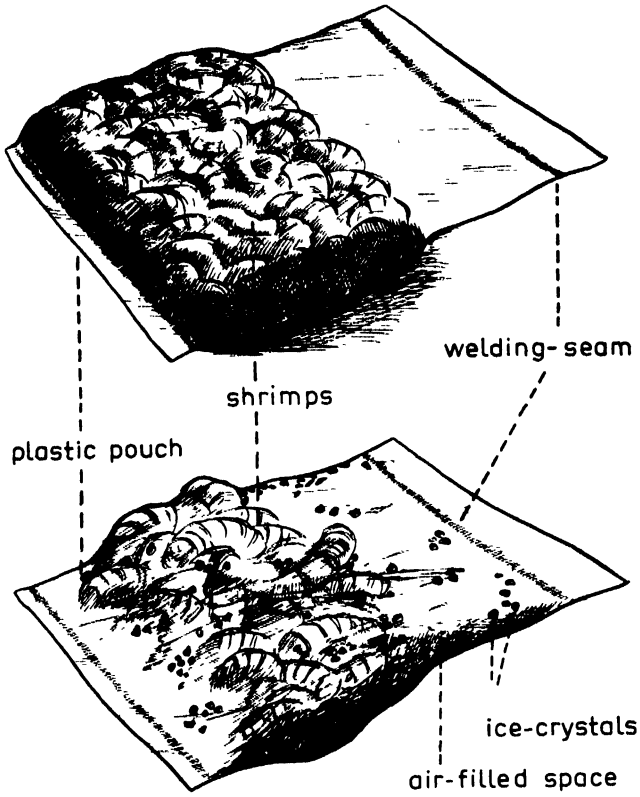


Fig 2. Two methods of packaging frozen peeled shrimps. Above: Vacuum-packed. This protects the meat effectively against desiccation and oxidation. Below: A heat-sealed plastic pouch, which has not been evacuated. Note the formation of ice crystals in the package. In such a package the frozen shrimps will very quickly become inedible

the frozen meat. Great improvement has been made in recent years by the introduction of vacuum-packing in air-tight plastic film prior to freezing. This procedure completely eliminates weight loss and evaporation inside the package and minimizes oxidation of pigments, fats and flavour ingredients (Anon., 1961b; Karsti and Hakvag, 1961).

Peeled meat, which is vacuum-packed in sealed plastic bags, may be heated or cooled rapidly provided that the maximum thickness of the package is small. Prior to freezing, the contents of thin packages may be pasteurized by immersion for a few minutes in a current of water holding a temperature of 80°C (176°F). The pasteurized packages should be chilled rapidly in cold water in order to preserve the yield and quality of the meat (Thomsen and Hansen, 1966).

Freezing and cold storage

Rock lobster tails have been frozen experimentally in agitated refrigerated brine, in a laboratory plate freezer or in still cold air (Anon., 1964, 1965a). The most rapid freezing was obtained in brine, for which a freezing time for single tails of 35 min is quoted. Plate freezing of tails in 4-cm thick layers lasted about 1½ to 2 h with plate temperatures about −45°C (−50°F). Plate freezing was found to be about four times as fast as freezing in still air.

The influence of the rate of freezing on the quality of raw or pre-cooked rock lobsters has been investigated (Anon., 1965a). Freezing to −18°C (0°F) lasting 8 h or 80 h, respectively, was compared. The rate of freezing had no noticeable effect on the cooked lobster. In the case of frozen lobster stored raw, the quick-frozen lobster was thought to have a superior flavour.

American companies have recently adapted liquid nitrogen freezing to shrimps and claim a better product and lower dehydration losses (Anon., 1965b). Freezing in liquid nitrogen sprays is a matter of minutes.

Freezing by direct immersion in liquid nitrogen is too drastic. Rock lobster tails, which were immersed in liquid nitrogen until boiling ceased after about 10 to 15 min, showed severe cracking, and the flesh was crumbly after subsequent thawing and cooking.

A study of the discolouration of frozen rock lobster tails indicates that the storage temperature is more important than the freezing rate (Anon., 1961a). Numerous reports emphasize the importance of maintaining a low storage temperature in any prolonged cold storage of crustacea. For crab meat storage it is stated that for storage up to three months the temperature should not be higher than −21°C (−5°F). As an approximate rule, it can be stated that the temperature of storage should be 3 degC (5 degF) lower than this for each additional increment of three months (Montgomery, 1966).

MOLLUSCS

The molluscs exploited by man are divided into three classes: the pelecypods or bi-valves like oysters, scallops, mussels and cockles; the gastropods like abalones and winkles; and the cephalopods like squids and cuttlefishes. World landings in 1965 (FAO, 1966) amounted to a total of 2.88 million t of live weight molluscs. In table 1 are given values for the landings of the most common species of molluscs in 1965 (FAO, 1966). These values include the weights of the shells, which constitute a major portion of the live weight of all molluscs except cephalopods. In table 2 are given values for the edible content of some molluscs (Soudan, Anquez and Bénézit, 1965).

TABLE 1. WORLD LANDINGS OF LIFE-WEIGHT MOLLUSCS IN 1965

		(1,000 *t*)
Bi-valves	Clams, cockles (Teleodesmacea)	470
	Mussels (Mytilidae, Arcidae)	303
	Oysters (Ostreidae)	735
	Scallops (Pectinidae)	180
	Total	1,688
Gastropods	Abalones, winkles (Gastropoda)	37
Cephalopods	Cuttlefishes (*Sepia* spp., *Sepiella* spp.)	67
	Octopuses (*Octopus* spp., *Polypus* spp., *Eledone* spp.)	136
	Squids (Loliginidae, Ommastrephidae)	(635)
	Total	838
Molluscs	Total	2,880

TABLE 2. EDIBLE CONTENT OF SOME MOLLUSCS
(Percentage of weight in shell)

Bi-valves	Hard clam or Quahag (*Venus verrucosa*)	13.4–15.1
	Mussel *Mytilus edulis*	7.7–19.3
	Oyster	
	(*Ostrea edulis*)	4.8–15
	(*Gryphea angulata*)	10–13
	Scallop (*Pecten maximus*)	20–30
Gastropods	Abalone (*Haliotis tuberculata*)	44
Cephalopods	Squid (*Ommastrephes sloani*)	77.4–81.5

About one-third of the total catch of molluscs in 1965 was landed in Japan and about one-fourth in North America, i.e. the United States and Canada (FAO, 1966). The fishery for cephalopods was concentrated in Japanese waters (two-thirds of the total catch) and in the Mediterranean (one sixth of the total catch). Scallops were almost entirely harvested in North America (85 per cent), while mussels were taken mainly in European waters (85 per cent). Fifty per cent of the total catch of oysters and 40 per cent of the clams and cockles were landed in the United States, the Japanese having caught 28 per cent and 37 per cent respectively.

Molluscs are marketed in a variety of forms and may be bought live, chilled, canned, semi-preserved or dried. According to literature, freezing too is taking place on a commercial scale to preserve both cephalopods (Borgstrøm, 1962; Fields, 1950), gastropods (Anon, 1951; Fowler and Jantjies, 1966; Montgomery, 1966) and bi-valves like oysters (Anon, 1960b; McKee, 1963; Shelton, 1965), scallops (Anon, 1966c; Martin, 1965; McKee, 1963) and clams (Tressler and Evers, 1957). Squids and cuttlefish seem to be the molluscs to which freezing preservation is applied to the greatest extent. In Japan, in 1964, more than 25 per cent of all landings of cephalopods was frozen (FAO, 1965; 1966). In Argentina, freezing of octopuses at sea started in 1966 (Anon, 1966b).

Freezing of cephalopods

Freezing of squids for the domestic market started in the United States about 1926, and the demand for the frozen product is reported to have increased up to 1950 (Fields, 1950). Despite this early interest in freezing cephalopods and the big amount of cephalopods frozen in Japan, literature on the subject is sparse. This may be due to the fact that freezing of squids in Japan is primarily done for two purposes: (1) as a means of supplying squids to the fresh fish market, i.e. defrosted squid, when landings of fresh squids are small, and (2) for use as bait (Borgstrøm, 1962). Especially the long-line fishing for tuna, in all countries, depends nowadays on frozen bait, and here squids are considered particularly desirable and efficient.

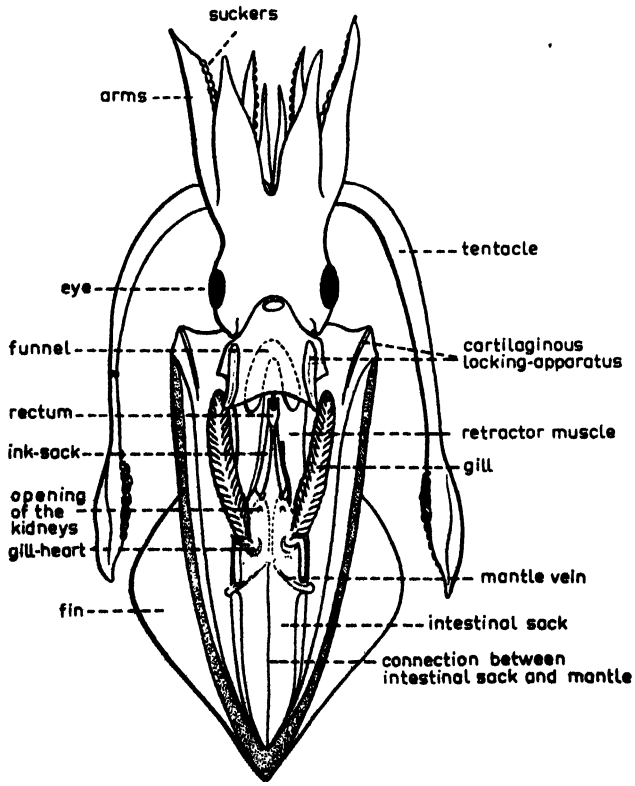


Fig 3. Internal features of squid

Some Japanese papers, however, comment on the changes occurring in the proteins of the cephalopod meat during freezing and storage. The protein content of cephalopod meat is about 11 to 15 per cent. Besides, there is rather a high content (about 0.6 to 1.1 per cent) of non-protein nitrogen in the meat (Soudan, Anquez and Bénézit, 1965). Tanikawa, Konno and Akiba (1953) have made investigations on the chemical changes in the meat of squid (*Ommastrephes sloani pacificus*), which had been frozen and stored for 80 days, and on the elasticity of jellies (kamaboko) made by steaming the thawed meat. During frozen storage they found few changes in pH and in the content of total volatile nitrogen (TVN), while there was a definite decrease in soluble nitrogen, especially the content of soluble protein nitrogen. During thawing of the frozen meat there may be a loss of the soluble non-protein nitrogen content and of the chemical constituents which contribute to the flavour and elasticity of the jellies. It was found that squid meat stored for 40–50 days could be used in the preparation of jellies. Another paper by Tanikawa, Akiba and Kawakami (1955) on the freezing of squid deals with the formation of drip formed by thawing the meat. The squids were frozen at −27°C (−17°F) and stored for various periods up to 45 days at −17°C (+1°F). It was found that the amount of total drip, measured as the sum of free drip and expressible drip, increased during the storage period and that the increase in drip formation was caused by a denaturation of proteins. Furthermore, the amounts of drip increased with decreasing freshness of the squid meat to be frozen. The loss of freshness was indicated by an increase in volatile nitrogen bases. Finally, it is claimed by Tanikawa, Akiba and Kawakami (1955) that adjusting the pH value of the meat is effective to a certain degree for preventing the formation of drip. The farther the pH value is from the isoelectric point (pH = 4.6) the less drip is formed. It is claimed too that pH values on the alkaline side of the isoelectric point are to be preferred.

In an Australian survey of the squid fisheries (Veteikis, 1966) it is said that squids are among the most numerous of all macroscopic animal life in the sea and that the supply seems almost inexhaustible. Furthermore, the eating quality of squid is claimed to be excellent. The author suggests increasing efforts as regards the fishing for cephalopods and concludes that the demand in Asia and the Mediterranean countries, where people are used to eating squid, suggests promising export outlets for frozen, dried or canned squid.

Freezing of gastropods

As can be seen from table 1, landings of gastropods are limited, and freezing of gastropods is consequently of minor importance.

Watermann (1963) mentions that the cooked meat of whelk (*Buccinum undatum*) may be quick-frozen and

stored. The whelks should not be cooked too long (8 to 10 min for small whelks and 15 to 20 min for the larger ones), since excessive boiling makes the meat very tough and difficult to remove from the shells. The freezing procedure, however, often makes the meat more tender. According to Watermann, whelks, for other than human consumption, are used for bait. The meat for bait can be more easily removed from the shell by first freezing and then thawing the whole whelks. The extracted meats can then be refrozen, if required, for storage as bait.

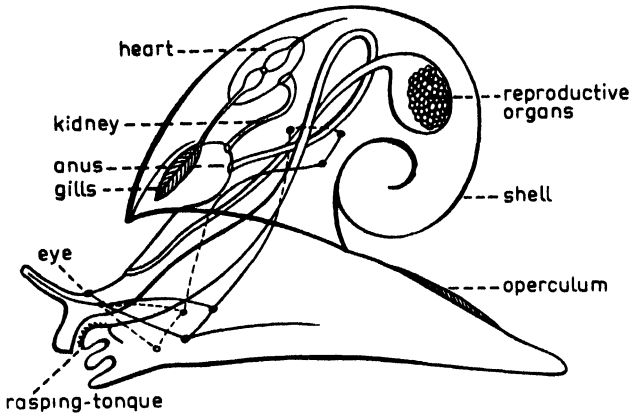


Fig 4. Internal features of whelk

Abalones, belonging to the family Haliotidae, are frozen in Australia (Montgomery, 1966), South Africa (Fowler and Jantjies, 1966) and the United States (Tressler and Evers, 1957) and are considered a delicacy (Pottinger, 1956). Like the other gastropods, abalones are univalves having a single shell, which surrounds the meaty portion called the foot or adductor muscle. Montgomery (1966) has given instructions for the processing of frozen abalones. Only abalone in live condition should be used for processing. The live abalone should first be shucked, i.e. the meat be removed from the shell. Then heart, stomach and intestines should be cut off and the meat quickly cooled to ice temperature, if it is not frozen immediately after evisceration. Direct contact with ice or ice water during cooling should be avoided. The meat might, for instance, be packed in a single layer in a polyethylene bag and covered with crushed ice. No longer than 15 h should elapse between shucking and freezing. If these recommendations are not followed the end-product may become stale and soft (Loetscher and Jantjies, 1964; Fowler and Jantjies, 1965). The meat should be frozen uncooked and the freezing performed quickly. It is recommended that the packs containing the abalones should not be thicker than 7 to 8 cm to allow a reasonably rapid freezing. During frozen storage care should be taken to prevent desiccation of the frozen meat, and the containers should be impervious to moisture and oxygen.

A storage temperature of about −20°C (−4°F) is recommended by Montgomery (1966), even though −15°C (5°F) may be acceptable. Le Roux (1953) investigated the influence of cold storage temperatures on the quality of raw frozen abalones. He found only inappreciable differences in the texture, colour and flavour of abalones which had been stored for up to six months at −18°C (0°F), −12°C (10°F) and −9°C (15°F).

Frozen abalones are used as raw material for canned abalones (Montgomery, 1966). Abalones which have been frozen more than once are not suitable for canning. When double-frozen abalones are thawed and canned a white curd may separate from the meat giving a milky appearance to the liquor in the can.

In the United States, small quantities of frozen abalone steaks were produced (Pottinger, 1956). After shucking and evisceration the meat was washed in fresh water. In a trimming operation the outer surfaces and the edge of the mantle were removed. Finally the muscles were sliced into steaks about 12 mm thick, and in order to make the meat more tender it was pounded on a block with a wooden mallet. The abalone trimmings from this production was used in a preparation of breaded frozen abalone patties (Anon, 1951). The pieces of abalone were minced in a mechanical grinder and the ground meat was forced under pressure into a metal tube and frozen. The frozen core was sliced into pieces 6.5 mm thick. These thin patties were battered and breaded and were ready for marketing after packaging.

Freezing of pelecypods

Oysters. Most of the research work, which has been done on the freezing of molluscs, concerns the bi-valves, and especially the freezing of oysters is well covered. The United States dominates oyster harvesting, and two species are of commercial value in this country, the eastern or Atlantic oyster (*Ostrea virginica*) and the Pacific oyster (*Crassostrea gigas*) (McKee, 1963). These are the species used in most experiments on freezing of oysters.

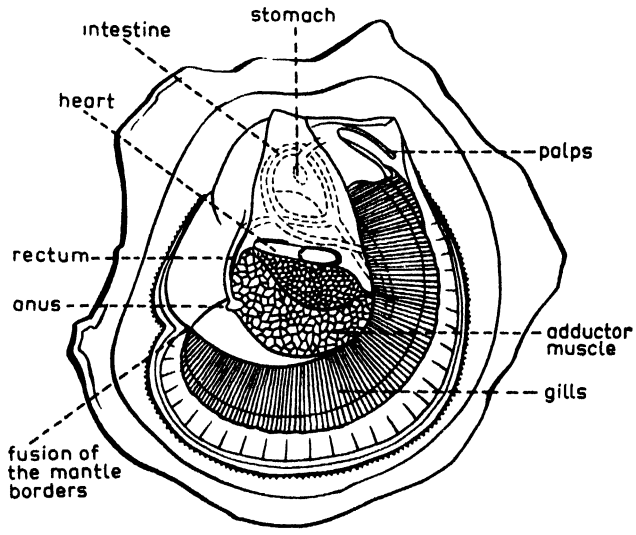


Fig 5. Internal features of oyster

Oysters may be frozen in a variety of forms. McKee (1963) describes marketing of raw shucked oyster meat frozen in metal containers; raw breaded oyster meat individually frozen in 5 or 10 lb (2.25 or 4.5 kg) cartons; frozen oyster stew, i.e. oyster meat mixed with spices and milk; and breaded, deep-fat fried oyster meat frozen and packaged in cartons. Japan exports raw shucked Pacific oysters individually frozen in polyethylene pouches (Anon, 1960b). In the United States, Pacific oysters are frozen too after blanching in boiling water for

1 min to firm the meat (Osterhaug and Nelson, 1957). Besides, experiments have been carried out to investigate the effect of freezing oysters in the shell (Sumerwell, 1955; van der Broek, 1950) and of freezing shucked, cooked oysters (Gardner and Watts, 1957; Schwartz and Watts, 1959).

The effects of freezing on oysters may vary considerably according to the product type. The result of organoleptic tests on thawed oysters will depend on how the oysters are prepared. Morton and Dyer (1956) have stated that stewing, baking or frying oysters in deep fat all masked the flavour and texture, while simmering the oysters made differences in texture and taste readily distinguishable. Examinations of frozen oysters showed a significant difference between rapidly-frozen oysters stored at −23°C (−9°F) and slowly-frozen oysters stored at −12°C (10°F) after one month's storage, when the oysters were thawed and prepared by simmering. As the storage period increased, the quality of the oysters decreased. If the thawed oysters were served as a stew no change could be detected throughout an eight-month storage period, nor was there any difference resulting from the various treatments.

This investigation makes it understandable why the reputation of frozen oysters may vary so much. Lanham, Kerr and Pottinger (1948) found that raw shucked oysters packed in cellophane and stored at −18°C (0°F) had a fine quality even after 12 months' storage, when the thawed meat was tested after breading and deep-fat frying. On the contrary, van der Broek (1950) referred to investigations, where raw shucked oysters packed in waxed cartons and stored at −20°C (−4°F) were found acceptable for three to four months. He found a considerable change in the frozen oysters in both texture and flavour, but the organoleptic tests, to which he referred, were carried out on the raw untreated thawed meat.

Only live oysters should be processed (Carlson, Carver and Heerdt, 1956). They may easily be distinguished from dead ones, as they will keep their shells closed when disturbed. It is not common to freeze the oyster in the shell. As can be seen from table 2 the meat constitutes only a small part of the total weight, and economic considerations, therefore, favour freezing of the shucked meat. Sumerwell (1955) mentions that there may be advantages in freezing oysters in the shell. In his investigations with Pacific oysters he found a smaller cook drip with oysters which had not been shucked before freezing, as compared with shucked oysters which were thawed and cooked in one operation. van der Broek (1950) found that freezing oysters in the shell gave a very poor product. Recent investigations at Torry Research Station (Anon, 1966a), however, indicate that freezing of another mollusc, namely, scallops (*Pecten maximus*) in the shell may give a good retention of quality if the meat is covered with a considerable layer of ice in and around the shell. Bad experience with freezing of unshucked oysters, therefore, may be due to unsatisfactory protection during cold storage.

After shucking, the oyster meat goes through different kinds of washing operations. It is common practice finally to "blow" the oysters, i.e. the oysters are washed with water, which is violently agitated by leading compressed air through openings in the bottom of the tank. Blowing is performed in order to remove sand, pieces of shells and other foreign matter (Pottinger, 1956). The blown oysters are left to drain before freezing. It has been established that the different washing procedures, especially the blowing, influence the quality of the frozen oyster. Osterhaug and Andrews (1955) found that increasing the blowing time resulted in a decrease in the dry matter content of the thawed, drained raw meat and in an increase in thaw drip. Lanham, Kerr and Pottinger (1948) found that raw oysters blown in fresh water increased in volume and that longer periods of blowing increased the values of free thaw drip. Blowing in weak (¾ per cent) salt solutions instead of plain water reduced the free thaw drip. The free thaw drip values did not increase with longer blowing times in the salt solutions. Spraying the oysters with plain water reduced the thaw drip too, compared with the values of the blown oysters. Investigations carried out by Fieger, Novak and Bailey (1959) confirmed that the thaw drip was reduced if the oysters were washed in salt solutions instead of plain water.

The amount of free drip, which is released when frozen oysters are thawed, is much larger than is common with frozen fish. Lanham, Kerr and Pottinger (1948) found an average of 26 per cent free drip from commercially-frozen oysters. As a consequence of the influence of the washing procedure on the amount of thaw drip, the U.S. Food and Drug Administration has stated that the total time during which oysters are in contact with water should not be more than 30 min (Pottinger, 1956).

The freshness of oysters to be frozen is very important (Osterhaug and Nelson, 1957; Pottinger, 1946; Sumerwell, 1955). If the oysters are not strictly fresh when frozen, they will deteriorate very quickly. This is in agreement with the fact that raw iced oysters lose their original flavour and deteriorate in taste after three days' storage (Takagi and Simidu, 1963).

The investigations of Morton and Dyer (1956) on the effect of the freezing rates on the quality of frozen raw oysters have already been mentioned. In these investigations it was found that raw shucked oysters, which had been quick-frozen in brine at −23°C (−9°F) packed in cans, kept well for at least nine months when stored at −23°C (−9°F). Oysters slowly frozen in an air current for about 15 h, deteriorated much faster when stored at −23°C (−9°F). After one month's storage the quality of the slowly-frozen samples was inferior to that of quick-frozen samples which had been stored for eight months. The samples were prepared by simmering. Quick-freezing seems to be important for the retention of quality.

Investigations in the United States (Anon., 1959) have compared freezing of unprotected oyster meat in brine-glucose solutions with freezing in air-blast. It was found that the immersion freezing was unsatisfactory due to an uptake of salt in the meat, which caused development of rancidity during storage. Air-blast freezing gave a good frozen product.

Different types of quality deteriorations of frozen oysters have been described. The appearance may be changed and discoloured in various ways. Some kind of black discolouration always seems to develop (Fieger, Novak and Bailey, 1959; Morton and Dyer, 1956; Osterhaug and Nelson, 1957; Pottinger, 1951a; Pottinger,

Kerr and Lanham, 1947). If the surfaces of the oysters are more or less freezer-burned they may turn yellow or brown (Osterhaug and Nelson, 1957; Pottinger, Kerr and Lanham, 1947). Finally a pink discolouration may develop during cold storage. Pink to red spots are seen on the oysters and the thaw drip is pink coloured. This type of discolouration is supposed to be caused by a micro-organism "pink yeast", which sometimes causes a pink discolouration in fresh oysters (Pottinger, 1956). It has been shown by McCormack (1950) that this micro-organism could grow even at −31°C (−24°F). McCormack has later on continued his work and reports in 1956 that the yeast, apparently belonging to the family Torulaceae, produces spores. No solutions to the problems of pink discolouration have been found, but Fieger, Novak and Bailey (1959) report that the use of antibiotics in the wash water may diminish discolourations. Pottinger (1956) emphasizes the need for following strict sanitary practice in the preparation of oysters for freezing, if pink discolouration is to be avoided.

During cold storage, frozen oysters may lose their crispness and firmness and become a little flabby (van der Broek, 1950; Osterhaug and Nelson, 1957; Pottinger, 1951a). Toughening of the meat may develop too (Anon, 1950; van der Broek, 1950). Texture changes, however, seem to contribute less to the deterioration of frozen oysters than do changes in taste. These changes are described as off-flavours (Anon, 1950; Pottinger, 1951a), bitter flavour (Osterhaug and Nelson, 1957) or rancidity (Anon, 1959; Gardner and Watts, 1957; Osterhaug and Nelson, 1957; Schwartz and Watts, 1959).

It is described below how different storage conditions may influence the above-mentioned signs of quality deterioration.

The effect of storage temperature has been investigated by Morton and Dyer (1956). They stored raw shucked oysters at −23°C (−9°F) and at −12°C (10°F) and found a rapid deterioration in texture and taste of the oysters, which were stored at −12°C (10°F), while the oysters stored at −23°C (−9°F) kept well for at least nine months. The oysters were organoleptically tested after simmering. If the oysters were prepared as a stew no difference could be detected. A slight darkening in the oysters appeared after two to three months' storage and intensified on storage. This reaction proceeded much further, when the oysters were stored at −12°C (10°F) than when stored at −23°C (−9°F).

Frozen oyster meat will deteriorate very readily if it is not protected well against drying of the surface (Pottinger, Kerr and Lanham, 1947) and against the influence of oxygen, which causes the lipids to become rancid (Anon., 1959; Gardner and Watts, 1957; Osterhaug and Nelson, 1957; Schwartz and Watts, 1959). Morton and Dyer (1956) found an average fat content of 2.7 per cent in Pacific oysters.

Different ways of protecting frozen oyster meat against surface desiccation have been described. Glazing was found to protect oysters against development of rancidity and to prolong storage life (Fieger, Novak and Bailey, 1959). If oysters were frozen individually it was found absolutely necessary to glaze the oysters, if they were not protected in other ways (Nelson, 1963). Freezing in bulk together with their own liquid makes the oysters much less susceptible to desiccation than freezing the oysters individually. Schwartz and Watts (1959) found that non-glazed bulk-frozen oysters showed lower TBA (thio-barbituric acid) values on storage at −20°C (−4°F) than individually-frozen oysters, even if these were protected with a glaze containing 1 per cent of the antioxidant ascorbic acid. Since the glazing layer gradually disappears during storage, it has been proposed to freeze the oysters in a liquid, which will make the oysters lie in a block of ice. The liquid could be the strained oyster liquor from the shucking operation (Anon., 1950).

If oysters are packed in materials with good moisture vapour retention and if these packages are completely filled up they have proved to give excellent protection. This was the case with cellophane-overwrapped cartons (Pottinger, Kerr and Lanham, 1947). As already mentioned, individually-frozen oysters were packed in pouches of polyethylene (Anon., 1960b). Polyethylene forms a water vapour barrier. Packaging in vacuum seemed to be advantageous (Fieger, Novak and Bailey 1959). It seems reasonable to pay more attention to vacuum packaging of frozen oysters.

Much work has been done in order to find out whether different kinds of antioxidant treatments could prevent unwanted flavour and colour changes in frozen oysters. Apparently the results are contradictory. Pottinger (1951b) treated raw oysters with ascorbic acid. The oysters were either dipped in 1 per cent solutions, or thoroughly mixed with 100, 200 or 300 mg ascorbic acid per 0.454 kg (1 lb) of oyster, or glazed with ascorbic acid solutions. Pottinger did not find any appreciable difference between treated and untreated samples. Osterhaug and Nelson (1957) found different antioxidants to have at least a limited effect in retarding oxidative changes in oysters frozen in hermetically-sealed containers. Nelson (1963) found no difference in the storage life of individually-frozen oysters, whether the oysters were glazed with different antioxidant solutions (including ascorbic acid) or with plain water. Gardner and Watts (1957) found that the quality deterioration in cooked frozen oysters was caused by oxidation and that it was reduced by treatments with antioxidants (liquid smoke, butylated hydroxy anisole (BHA) and nordihydroguaiaretic acid (NDGA).

In the above-mentioned investigations the oysters have been tested organoleptically for flavour changes. Schwartz and Watts (1957) have investigated the application of the TBA test as a quantitative measure of deterioration in cooked oysters, and they have later, in 1959, used this test on both raw and cooked frozen oysters. As already mentioned they found no consistent increase in TBA values of bulk-frozen oysters and consequently no effect of antioxidant treatment. Individually-frozen raw oysters, however, developed a rancid odour and increasing TBA values. The oxidative changes were retarded by the use of an ascorbic acid glaze, 1 per cent solutions being more effective than 0.5 per cent solutions. If the oysters were cooked prior to freezing in bulk they too developed rancid odour and higher TBA values. Adding 0.1 per cent ascorbic acid to the cooking water resulted in a definite decrease in rancidity and lower TBA values.

It was found too by Schwartz and Watts that the copper content in oysters, which may catalyse oxidation

of ascorbic acid and thus inhibit its action as an anti-oxidant, was better bound or chelated by the cooked oyster meat than by the raw meat. This explains why ascorbic acid treatment of cooked oyster meat seems so effective in retarding oxidation.

Mussels. The mussel (*Mytilus edulis*) is harvested in Europe, in particular. Early investigations on the freezing of mussels were rather disappointing as to the possibilities of preserving mussels in this way. Scattergood and Taylor (1949) found that little study had been carried out on the effect of long periods of cold storage on the flavour, appearance and nutritive values of frozen mussels. Mussels stored for four months had developed slightly bitter taste, dark colour and toughened texture. van der Broek (1950) said that freezing does not change taste and flavour to any great extent, while protein denaturation plays an important role. The mantle gets mealy and breaks into pieces, which makes the frozen cooked mussels nearly unacceptable in spite of an excellent taste. Investigations by Banks and House (1958), however, showed that by choosing the right conditions of cooking, freezing and cold storage, frozen mussel meat can be kept in a virtually unchanged condition for eight to nine months. This is in agreement with Danish experience (Anon., 1960a) saying that steamed, shucked and breaded mussels keep a good texture during cold storage.

As it is uneconomic to freeze mussels in the shell, they have to be shucked prior to freezing. Only live mussels should be processed. A live mussel is difficult to open, and the meat is usually torn (Scattergood and Taylor, 1949). Cooking causes the mussels to open and facilitates separation of the meats. Cooking procedure, however, influences the texture of the mussel, overcooking toughening the meat (Banks and House, 1958; Rietz and Wanderstock, 1965; Scattergood and Taylor, 1949). Banks and House found that steaming the mussels just sufficiently to open the shells and cooling the cooked mussels quickly with a water spray was the best method. Rietz and Wanderstock advocate wet cooking at 85°C (185°F). Contact with salt (from the cooking water or cleaning water) should be avoided prior to freezing, as it is found to accelerate off-flavours in the mussels after long-time storage (Banks and House).

During cold storage the meat should be protected against desiccation, for instance by glazing. A low storage temperature is also important. After three months' storage Banks and House found a slight toughening of texture and development of off-flavour in meat stored at −22°C (−8°F), while meat stored at −29°C (−20°F) differed very little from freshly-cooked meat after eight to nine months' storage. It was found that thawing the meat in 2.5 per cent salt solutions improved the flavour of the thawed mussels.

Scallops. Scallops, belonging to the family Pectinidae, are commonly preserved by freezing (Tressler and Evers, 1957). In the United States, which is the biggest market for frozen scallops, 8,190 t (18 million lb) were sold in 1964 (Martin, 1965). The scallops are shucked on board the vessels and only the adductor muscles or "eyes" are marketed. The rest of the molluscs are either discarded, frozen as bait or used as fertilizer (McKee, 1963). Frozen scallops are marketed in the breaded form either as the raw or the pre-cooked product. Recent investigations in Great Britain (Anon., 1966a) indicate that protection against oxidation and desiccation of the surface may facilitate retention of quality in frozen scallops.

Clams and cockles. Four different kinds of clams are processed and frozen in the United States (Tressler and Evers, 1957): the soft clam (*Mya arenaria*), the hard clam (*Venus mercenaria* and *Artica islandica*), the surf clam (*Mactra solidissima*), and the razor clam (*Siliqua patula*). All clams, and especially the surf clam, are said by Tressler and Evers (1957) to be well preserved by freezing. This statement is not in agreement with the contention of Pottinger (1956), according to which clams lose their quality relatively fast, when frozen, and become tough and spongy with a considerable loss of drip on being thawed. Watermann (1963) states that the cockle (*Cardium edule*) may be quick-frozen and cold-stored in the same way as mussels.

References

Crustacea

AAGAARD, J *Konserves og Dybfrost*, **23**(4), 38. 1965

ANDERSON, K W *Fd Preserv. Q.*, **16**, 4. 1956

ANON. *5th Annual Report 1951/52*, Fishing Industry Research 1952 Institute, Cape Town.

ANON. *8th Annual Report 1954/55, Ibid.* 1955

ANON. *11th Annual Report 1957, Ibid.* 1958

ANON. *14th Annual Report 1960, Ibid.* 1961a

ANON. *Annual Report 1960*, Fiskeriministeriets Forsøgs- 1961b laboratorium, Denmark.

ANON. *17th Annual Report 1963*, Fishing Industry Research 1964 Institute, Cape Town.

ANON. *18th Annual Report 1964, Ibid.* 1965a

ANON. *Fishg Gaz.*, **82**(4), 44. 1965b

ANON. *Annual Report 1965*, Fiskeriministeriets Forsøgs- 1966 laboratorium, Denmark.

BAILEY, M E and FEIGER, E A *Fd Technol., Champaign*, **8**(7), 1954 317.

DASSOW, J A *Comml Fish. Rev.*, **16**(7), 1. 1954

DASSOW, J A The crab and lobster fisheries. In *Industrial* 1963 *Fishery Technology*, ed. M. E. Stansby, Reinhold Publishing Corporation, New York, p. 193.

DENNELL, R Integument and exoskeleton. In *The Physiology*
1960 *of Crustacea*, ed. T. W. Waterman, **1**, 449.

DYER, W J and HORNE, D C *New Series Circular*, No. 2,
1953 Fisheries Research Board of Canada.

FARBER, L *Fd Technol., Champaign*, **7** (11), 465.
1953

FAULKNER, M B and WATTS B M *Ibid.*, **9**(12), 632.
1955

GETCHELL, J S and HIGHLANDS, M E Processing lobster and
1957 lobster meat for freezing and storage. *Bulletin* 558, Maine Agricultural Experiment Station, University of Maine.

GOODWIN, T W Biochemistry of pigments. In *The Physiology*
1960 *of Crustacea*, ed. T. W. Waterman, **1**, 101.

HEERDT, E and DASSOW, J A *Comml Fish. Rev.*, **14**(12a), 29.
1952

HOVART, P and VYNCKE, W *Fishg News int.*, **3**(3), 227.
1964

KARSTI, O and HAKVÄG, D *Fisk Dir. Skr.*, Reports on tech-
1961 nological research concerning Norwegian fish industry, 4(1).

MAYNARD, D M Circulation and heart function. In *The*
1960 *Physiology of Crustacea*, ed. T. W. Waterman, **1**, 161.

MONTGOMERY, W A *Fish. Newsl., Canberra*, **25**(5), 23.
1966

OSAKABE, J *Refrigeration, Jap.*, **36**, 979.
1961

ROBERTSON, J D Osmotic and ionic regulation. In *The*
1960 *Physiology of Crustacea*, ed. T. W. Waterman, **1**, 317.

THOMSEN, B F and HANSEN, P (MS.)
1966

Molluscs

ANON. *Ice Refrig.*, **119**(4), 64.
1950

ANON. *Pacif. Fisherm.*, **49**(6), 51.
1951

ANON. *Comml Fish. Rev.*, **21**(8), 15.
1959

ANON. *Annual Report 1959*, Fiskeriministeriets Forsøgs-
1960a laboratorium, Denmark.

ANON. *Pacif. Fisherm.*, **58**(9), 9.
1960b

ANON. *Annual Report 1965*, Torry Research Station, Aber-
1966a deen.

ANON. *Fishg News int.*, **5**(11), 12.
1966b

ANON. *Ibid.*, **5**(11), 11.
1966c

BANKS, A and HOUSE, C T *Mod. Refrig.*, **61**(724), 686.
1958

BORGSTRØM, G Trends in utilization of fish and shellfish. In
1962 *Fish as Food*, ed. G. Borgstrøm, Academic Press, New York, **2**, 637.

BROEK, C J H VAN DER *Some Aspects of Food Refrigeration*
1950 *and Freezing*. Agricultural Studies, No. 12, FAO, Rome, p. 134.

CARLSON, C J, CARVER, J and HEERDT, M Handling fresh fish
1956 at the shore plant. In *Refrigeration of Fish—Part 2*, Fishery Leaflet 428, U.S. Fish and Wildlife Service, Washington, D.C., 39–84.

EMPEY, W A *Fish. Newsl., Canberra*, **13**(4), 9.
1954

FAO *Yb. Fish. Statist.*, FAO, Rome, p. 19.
1965

FAO *Ibid.*, p. 20.
1966

FIEGER, E A, NOVAK, A F and BAILEY, M E *Quick froz. Fds*
1959 *int.*, **22**(11), 72.

FIELDS, G W *Calif. Fish Game*, **38**(4), 366.
1950

FOWLER, G DE V and JANTJIES, M *18th Annual Report 1964*,
1965 Fishing Industry Research Institute, Cape Town, p. 93.

FOWLER, G DE V and JANTJIES, M *19th Annual Report 1965*,
1966 Fishing Industry Research Institute, Cape Town, p. 85.

GARDNER, E A and WATTS, B M *Fd Technol., Champaign*,
1957 **11**(1), 6.

LANHAM, W B, KERR, R G and POTTINGER, S R *Fd Inds*,
1948 **20**(2), 220.

LOETSCHER, K M and JANTJIES, M *17th Annual Report 1963*,
1964 Fishing Industry Research Institute, Cape Town, p. 77.

MARTIN, S *Quick froz. Fds int.*, **28**(11), 36.
1965

MCCORMACK, G *Comml Fish. Rev.*, **12**(11a), 28.
1950

MCCORMACK, G *Ibid.*, **18**(11), 21.
1956

MCKEE, LYNNE G The oyster, clam, scallop and abalone
1963 fisheries. In *Industrial Fishery Technology*, ed. M. E. Stansby, Reinhold Publishing Corporation, New York. Chapter 13,

MONTGOMERY, W A *Fish. Newsl., Canberra*, **25**, 23.
1966

MORTON, M L and DYER, W J *J. Fish. Res. Bd Can.*, **13**(1), 47.
1956

NELSON, R W *Comml Fish. Rev.*, **25**(4), 1.
1963

OSTERHAUG, K L and ANDREWS, M *Ibid.*, **17**(12), 11.
1955

OSTERHAUG, K L and NELSON, R W *Ibid.*, **19**(6), 10.
1957

POTTINGER, S R *Am. Cookery*, **51**(7), 24.
1946

POTTINGER, S R *Comml Fish. Rev.*, **13**(10), 1.
1951a

POTTINGER, S R *Ibid.*, **13**(7), 5.
1951b

POTTINGER, S R Shellfish. In *Refrigeration of Fish—Part 4*,
1956 Fishery Leaflet 430, U.S. Fish and Wildlife Service, Washington, D.C., pp. 37–72.

POTTINGER, S R, KERR, R G and LANHAM, W B *Fd Inds*,
1947 **19**(3), 324.

RIETZ, C A and WANDERSTOCK, J J *A Guide to the Selection*,
1965 *Combination and Cooking of Foods*, **2**, chapter 37.

ROUX, G J LE *6th Annual Report 1952/53*, Fishing Industry
1953 Research Institute, Cape Town, p. 15.

SCATTERGOOD, L W and TAYLOR, C C *Comml Fish. Rev.*,
1949 **11**(10), 8.

SHELTON, D D *Quick froz. Fds int.*, **28**(9), 97.
1965

SCHWARTZ, M G and WATTS, B M *Fd Res., Champaign*, **22**,
1957 76.

SCHWARTZ, M G and WATTS, B M *Comml Fish. Rev.*, **21**(3), 1.
1959

SOUDAN, FRANCE, ANQUEZ, M and BÉNÉZIT, A *La Conserva-*
1965 *tion par le Froid des Poissons, Crustacés et Mollusques*, Baillière et fils, Paris, 514 pp.

SUMERWELL, W N *Comml Fish. Rev.*, **17**(3), 18.
1955

TAKAGI, I and SIMIDU, W *Bull. Jap. Soc. scient. Fish.*, **29**(1),
1963 71.

TANIKAWA, E, KONNO T and AKIBA, S *Bull. Fac. Fish.*
1953 *Hokkaido Univ.*, **4**, 224.

TANIKAWA, E, AKIBA, M and KAWAKAMI, K On the forma-
1955 tion of "drip" in the freezing of squid meat. *Proc. IX Int. Congr. Refrig.*, Paris, p. 4058.

TRESSLER, D K and EVERS, C F *The Freezing Preservation of*
1957 *Foods*, **1**, Chapter 20.

VETEIKIS, J J *Fish. Newsl., Canberra*, **25**(6), 26.
1966

WATERMAN, J J Processing mussels, cockles and whelks.
1963 *Torry Advis. Note*, No. 13. Torry Research Station, Aberdeen.

A Comparison of the Quality of Frozen Plaice Fillets Prepared from Fresh or Frozen Raw Materials

by P. Hansen

A comparison of the quality of frozen plaice fillets prepared from fresh or frozen raw materials

Small plaice are an important raw material in the Danish fillet freezing industry. Landings of iced plaice are irregular and do not provide steady supplies to the industry. Bulk freezing of raw material, however, affords a means of preserving surplus catches until they can be thawed and filleted at times when catches are low.

The effects of single and double freezing on the quality of plaice fillets were investigated. Within different seasons, gutted plaice, which had previously been iced for three to five or for 10 to 13 days, were processed either by filleting, retail packing and freezing, i.e. the normal procedure, or by bulk freezing, cold storage, thawing, filleting, retail packing and freezing. After some additional weeks of cold storage the eating qualities of cooked samples of single and double-frozen fillets were compared.

The quality of fillets produced from plaice caught in the late autumn and iced for more than five days was not affected by the number of times that they were frozen. When this plaice was iced for 10 to 13 days prior to processing, double freezing resulted in some deterioration of the eating quality as compared with single freezing.

The eating quality of fillets produced from plaice which were caught in spring or in summer depended on the number of times they had been frozen. Double freezing resulted in some deterioration.

The eating quality was measured on a 10 (ideal) to 0 (poor) hedonic scale. Deteriorations due to double freezing when found were of the order of one scale unit and did not reduce the quality to below edibility.

Comparaison entre la qualité des filets de plie congelés selon qu'ils sont préparés à partir de matière première fraîche ou congelée

Les petites plies constituent une importante matière première pour l'industrie danoise des filets congelés. Les apports de plie sous glace sont irréguliers et ne peuvent alimenter régulièrement l'industrie. Toutefois, la congélation en masse de la matière première permet de conserver les excédents de captures, qui peuvent être décongelés et filetés lorsque les prises sont en baisse.

On a étudié l'effet de la simple et de la double congélation sur la qualité des filets de plie. A différentes saisons, des plies éviscérées, auparavant mises sous glace de trois à cinq jours ou de 10 à 13 jours, ont été soumises, d'une part à la méthode ordinaire—filetage, empaquetage en portions individuelles et congélation—et d'autre part aux opérations suivantes: congélation en vrac, entreposage réfrigéré, décongélation, filetage, empaquetage et congélation. Après quelques semaines en chambre froide, on a comparé les qualités gustatives, après cuisson, d'échantillons de filets de ces deux catégories.

La qualité des filets obtenus à partir de plies pêchées en fin d'automne et mises sous glace plus de cinq jours n'a pas été affectée par le nombre de congélations. Lorsque les mêmes plies sont restées sous glace de 10 à 13 jours avant leur traitement, la double congélation a causé une certaine altération des qualités gustatives par rapport à la congélation simple.

La comestibilité des filets de plies pêchées au printemps ou en été a dépendu du nombre de congélations, la double congélation causant une certaine altération.

Les qualités gustatives ont été notées de 0 (médiocre) à 10 (idéal) par la méthode du jury de dégustation. Les altérations éventuelles dues à la double congélation étaient de l'ordre d'une unité et n'affectaient pas la comestibilité du produit.

Comparación de la calidad de los filetes de solla congelados preparados con materia prima fresca o congelada

La solla pequeña constituye una importante materia prima en la industria danesa de congelación de filetes. Los desembarques de solla con hielo son irregulares y no proporcionan suministros constantes a la industria. Sin embargo, la congelación en masa de la materia prima proporciona un medio de conservación de las capturas excedentes hasta que se pueden descongelar y prepararse en filetes durante los períodos en que escasean las capturas.

Se investigaron los efectos del congelamiento sencillo y doble sobre la calidad de los filetes de solla. En temporadas diferentes, las sollas evisceradas, que habían sido mantenidas previamente en hielo durante tres–cinco ó 10–13 días, se elaboraron mediante fileteado, envasado para la venta al por menor y congelación, es decir, por el procedimiento normal o mediante congelación en masa, almacenamiento refrigerado, descongelación, fileteado y envasado para la venta al por menor y congelación. Después de unas semanas más de almacenamiento refrigerado se compararon las calidades comestibles de las muestras cocinadas de los filetes congelados una y dos veces.

En la calidad de los filetes de solla capturada a final del otoño y mantenida en hielo durante más de cinco días no influyó el número de veces que aquéllos se congelaron. Cuando esta solla se mantuvo en hielo durante 10 a 13 días antes de la elaboración, la congelación doble originó cierta alteración de la calidad comestible en comparación con la congelación sencilla.

La calidad comestible se midió aplicando una escala de 0 (malo) a 10 (ideal). Se encontró que la deterioración debida a la congelación doble era del orden de una unidad de la escala y no reducía la calidad hasta hacer el producto incomestible.

IN Danish sea fisheries, small plaice (*Pleuronectes platessa*) are eviscerated and washed immediately after catching. Afterwards they are buried in wet ice in the fish hold. At the time of landing, the catches contain fish which have been stored for various lengths of time up to two weeks, which is the maximum storage life under these conditions. In order to level out fluctuations in the supply of raw material to the plaice filleting industry some of the freshest fish landed may sometimes be stored in ice for a few additional days before processing. Bulk freezing of raw material, however, affords a more effective means of preserving surplus catches until they can be thawed and filleted at times of scarcity.

Experimental bulk freezing of eviscerated small plaice on landing has been undertaken in order to ascertain the effect of subsequent thawing, filleting and refreezing on the quality of the fillets. Double-frozen fillets were compared with single-frozen fillets prepared from plaice of the same catch. Ice storage prior to freezing was the same in both cases. Table 1 concerns fillets of fish ice-stored for three to five days and table 2 fillets of fish ice-stored for 10 to 13 days prior to freezing.

TABLE 1. AVERAGE TASTE SCORES. PLAICE ICED FOR THREE TO FIVE DAYS PRIOR TO FREEZING

Time of catch	*Single-frozen fillets*	*Double-frozen fillets*
March	6.4	5.0
	6.5	6.0
	6.1	5.1
July	6.8	5.4
September	6.5	5.4
	6.6	5.7
October	7.4	7.7
	6.5	6.2
November	6.7	7.0
	5.1	5.9

TABLE 2. AVERAGE TASTE SCORES. PLAICE ICED FOR 10 TO 13 DAYS PRIOR TO FREEZING

Time of catch	*Single-frozen fillets*	*Double-frozen fillets*
October	7.3	6.4
	6.3	5.8
	6.4	5.3
November	6.9	5.8

The plaice were packed for bulk freezing in aluminium trays in a layer about 6 cm thick. After freezing according to normal industrial procedures, the blocks were removed from the trays, glazed and packed in polyethylene bags. The blocks were cold-stored at about −25°C (−13°F) for one to three months. The blocks were thawed in a blast of moist air or between metal plates maintained at a temperature not higher than 23°C (73°F). Thawing lasted about 4 to 5 h. The thawed fish were filleted, packed and frozen according to normal industrial procedures identical to those used in the processing of the single-frozen fillets from non-frozen raw material.

The data shown in the tables gives average scores for the eating quality of thawed fillets cooked in lightly salted water at 80°C (176°F) for 15 min. Scores were given according to a 10 to 0 hedonic scale, where 10 represents the ideal quality, 8 good, 6 fair and 4 borderline qualities.

The quality of double-frozen fillets is as good as that of single frozen fillets as regards fish caught in October and November. This is the season of highest quality of Danish-caught plaice. Outside this period single-frozen fillets were always found superior to double-frozen fillets, although the latter in no case showed unacceptable quality.

In this case single-frozen fillets were found superior to double-frozen fillets.

Similar experiments with plaice which had previously been iced for nought to five days showed that freezing of the fish before or at the beginning of the *rigor mortis* period does not give a better quality to the finished product than freezing after three to five days of iced storage, i.e. at the end of the *rigor* period. The latter procedure tends to give a more uniform quality to the fillets.

CONCLUSION

Plaice caught in October or November in the Danish sea fishery and iced for no longer than five days may be processed to single- or double-frozen fillets with equally good results. When the plaice are caught outside this period or iced for 10 to 13 days single-frozen fillets are superior to double-frozen fillets. The quality loss due to double freezing is similar in kind to quality losses due to prolonged cold storage.

Discolouration of Tuna Meat and Red-skin Fish During Frozen Storage

by K. Amano, M. Bito and N. Tsukuda

Discolouration of tuna meat and red-skin fish during frozen storage

As a part of the study on the discolouration of frozen tuna meat, occurrence of a more developed metmyoglobin formation in the inner tissue was examined in relation to temperature. During short periods of storage between −3°C (27°F) and −10°C (14°F) a more marked discolouration always develops in the inner tissue than the surface, possibly due to a lower oxygen partial pressure. The situation may also occur in the surface meat of tuna, for example, by applying a thick ice glaze, whereby oxygen may become reduced to such a degree as to accelerate the discolouration. Therefore, ice glaze treatment may not be practical for frozen tuna, though it is useful for most frozen fish. The difference in the temperature for maximum discolouration was discussed from viewpoints of both oxygen partial pressure and specific temperatures near −3° to −4°C (27° to 25°F) which may reduce pH or increase salt concentrations. The control of the partial pressure of oxygen in the inner tissue would seem to be the key to prevent the discolouration of frozen tuna.

Enzymatic action to enhance the discolouration of astaxanthin or tunaxanthin was discovered in the skin of rockfish, though the effect of light may be presumed a more significant factor in the actual discolouration. Examinations of the preventive effect of coloured cellophane revealed that red cellophane film was found most effective to protect the skin colour of red fish. The wavelength between 330 and 380 mμ may be the most influential on the colour fading of these fish.

Décoloration de la chair du thon et des poissons à peau rouge durant l'entreposage sous congélation

Dans le cadre de l'étude sur la décoloration de la chair de thon congelé, on a examiné les rapports entre température et formation plus marquée de metmyoglobine à l'intérieur des tissus. Pendant de brèves périodes d'entreposage à des températures variant entre −3°C (27°F) et −10°C (14°F), la décoloration est toujours plus forte à l'intérieur des tissus qu'à la surface, peut-être du fait de la diminution de la pression partielle d'oxygène. Le phénomène peut également se produire à la surface de la chair de thon, par exemple en cas d'enrobage dans une couche de glace épaisse, qui peut réduire la pression de l'oxygène au point d'accélérer la décoloration. Aussi le givrage technique qui est utile pour la plupart des poissons congelés, peut ne pas convenir au thon. La différence entre les températures provoquant le maximum de décoloration est examinée des points de vue tant de la pression partielle de l'oxygène que de températures spécifiques voisines de −3° à −4°C (27° à 25°F), susceptibles d'abaisser le pH ou d'accroître la concentration en sels. Il semblerait possible d'éviter la décoloration du thon congelé en agissant sur la pression partielle de l'oxygène à l'intérieur des tissus.

On a mis à jour la présence d'une action enzymatique dans la peau du "rockfish" (Scorpaenidae) qui favoriserait la décoloration de l'astaxanthine ou de la tunaxanthine, quoique l'effet de la lumière puisse être tenu pour un facteur plus important de la décoloration. Lors d'études sur l'effet préventif de la cellophane colorée, on a constaté que pour préserver la coloration des poissons à peau rouge, c'est la cellophane rouge qui donnait les meilleurs résultats. La décoloration de ces poissons pourrait être causée principalement par les radiations de 330 à 380 millimicrons de longueur d'onde.

Cambio de color de la carne de atun y del pescado de piel roja durante el almacenamiento frigorífico

Como parte del estudio sobre el cambio de color de la carne de atún congelado se examinó, en relación con la temperatura, la aparición de una formación más desarrollada de metamioglobina en el tejido interior. Durante cortos períodos de almacenamiento entre −3°C (27°F) y −10°C (14°F) se produce siempre un cambio de color más acentuado en el tejido interior que en la superficie, posiblemente debido a una presión parcial del oxígeno más baja. La situación se puede producir también en la carne superficial del atún, por ejemplo, aplicando una capa gruesa de glaseado con lo que el oxígeno se puede reducir en tal grado que acelere el cambio de color. Por esto, el tratamiento con el glaseado es posible que no sea práctico para el atún congelado, aunque es útil para la mayoría del pescado congelado. Se examinó la diferencia en la temperatura para el cambio de color máximo desde el punto de vista tanto de la presión parcial del oxígeno como de temperaturas específicas próximas a −3° ó −4°C (27° ó 25°F) que pueden reducir el pH o aumentar las concentraciones de sal. El control de la presión parcial del oxígeno en el tejido interior parece constituir la clave para evitar el cambio de color del atún congelado.

Se comprobó la acción enzimática para aumentar el cambio de color de la astaxantina o tunaxantina en la piel del cabracho, aunque el efecto de la luz es de suponer que constituya un factor más importante en el cambio de color real. Los exámenes del efecto preventivo del celofán de color revelaron que la película de celofán rojo era más eficaz para proteger el color de la piel de los peces rojos. La longitud de onda entre 330 y 380 mμ puede constituir el factor más influyente sobre la pérdida de color de estos peces.

SINCE the market price of frozen tuna meat is subjected to a wide variation by the meat colour on thawing, the prevention of discolouration has been a great concern in the tuna fishing industry, especially in production frozen at sea.

In a series of studies on the retention of meat colour of frozen tuna, Bito (1964) pointed out that a remarkable discolouration took place in the interior portion of frozen tuna at −20°C (−4°F), a temperature that had conventionally been practiced by the tuna industry. Bito (1965) recommended a temperature below −35°C (−31°F) for the storage of tuna based on his findings that only 20 to 35 per cent of metmyoglobin was demonstrated in tuna meat at this temperature even after one year's storage. It was also found that the discolouration developed more rapidly at −5°C (23°F) than 0°C (32°F). These observations seemed to suggest that oxygen relationship may be very important at the site of discolouration. Part of this paper will report the significant role of oxygen partial pressure on the discolouration of frozen tuna meat.

The species with red skin are likely to lose their colour even under frozen storage. Tsukuda and Amano (1966b) observed that only about 26 per cent of total carotenoid pigments in the skin of gurnard fish (*Chelidonichthys kumu*) at −3°C (27°F) after 35 days, while 78 per cent were found at −30°C (−22°F) after 75 days' storage. The discolouration would proceed quicker in commercial practice, since the results obtained were from samples kept under complete darkness. This finding may imply that certain factors other than light could be related to discolouration. As a preventive of discolouration, some

trials using antioxidants (Yamaga and Morioka, 1962) or the use of inert gas in the packages have been proposed (Lusk *et al.*, 1964). In the latter part of the present paper, the writers described the occurrence of a biological factor on skin discolouration of red fish and a possible use of coloured wrapping as a preventive.

EXPERIMENTS AND RESULTS

Difference in the rate of metmyoglobin formation between surface and inner meat of frozen tuna

Bluefin tuna meat (*Thunnus orientalis*) purchased from Tokyo Central Fish Market from July to October 1965 was used in this experiment. The fish had been caught in the north-eastern part of the coastal sea of the country. The blocks were frozen at −80°C (−112°F) for 2 h and then placed into sealed polyethylene bags. The size of each cut was 3 × 3 × 3 cm and were stored at different temperatures from −3° to −10°C (27° to 14°F) at intervals of one day for four days. Deviation in the temperatures was ±0.2 degC (±0.36 degF). As an index of discolouration metmyoglobin percentage was determined according to Bito's method (1965). Soluble protein was determined on the supernatant obtained by centrifuge of the extract, prepared from 15 g of meat in 0.6 M KCl solution of 300 ml at 6,000 rev/min for 30 min.

Fig 1 shows the difference in the rate of metmyoglobin formation during short-term storage. It is of interest to know that the temperature of maximum colouration can be readily discerned from the portion of meat. The

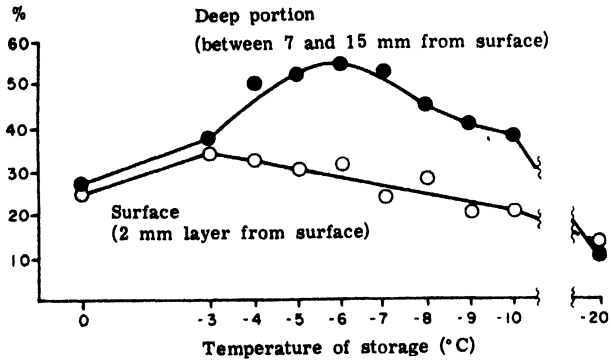


Fig 1. Formation of metmyoglobin in bluefin tuna meat (3×3×3 cm, pH 5.70 to 5.75) stored for four days at various temperatures

greatest discolouration in the surface portion is at −3°C (27°F) while in the inner part it is −6°C (21°F). Repeated experiments indicated quite reproducible results and the maximum temperature for discolouration was found at the surface layer in a range of −3° to −4°C (27° to 25°F) and at the inner layer −6° to −7°C (21° to 19°F).

No correlation was noted between the degree of meat discolouration and the amount of salt-extractable protein or water-soluble protein.

Preventive effect of ice glaze or film packaging

Ice glaze treatment has been practiced by the freezing industry for many years as a useful means of protection from desiccation and subsequent quality deterioration. The effect of ice glaze on frozen tuna meat was examined by varying the thickness of glaze. Fresh yellowfin tuna meat (*Thunnus albacares*) pieces 2 × 2 × 3 cm and frozen at −80°C (−112°F). Three sets of samples were prepared, in which the first one was glazed with 5 mm thickness of ice, the second with 0.3 mm, and the third sealed in a polyethylene bag unglazed. These samples were then stored at −20°C (−4°F) for eight weeks and examined for metmyoglobin once a week. Fig. 2 shows no appreciable difference of metmyoglobin formation among the three groups during the first four weeks of storage, but afterwards the meat covered with the thick glaze showed a rapid increase in metmyoglobin. In this particular case, the ice coverings give an adverse effect on the colour retention.

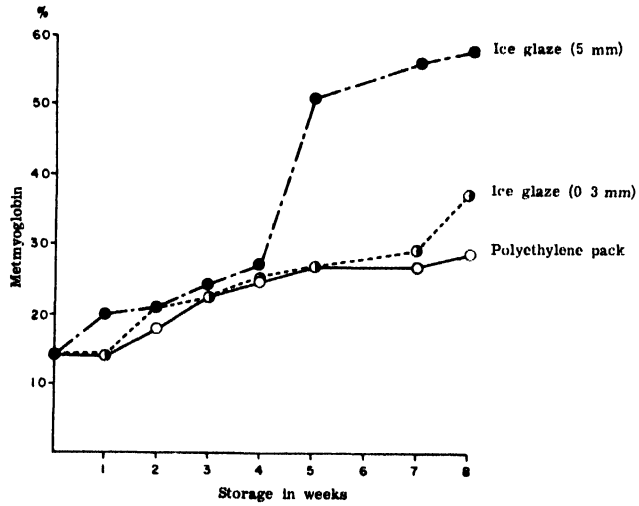


Fig 2. Effect of ice glaze on the frozen flesh of yellowfin tuna on metmyoglobin formation during frozen storage at - 20°C (size of flesh, 2×2×3 cm)

Discolouration of carotenoid pigments by fresh skin homogenate

A rockfish (*Sebastolobus macrochir*) was used for the preparation of astaxanthin (AxE) and tunaxanthin, two major carotenoid pigments in the skin of red fish. Skin and fins were extracted by acetone after dehydration with anhydrous sodium sulphate. The concentrated carotenoids in the acetone extract were then transferred to petroleum ether and were subjected to column chromatographic separation using aluminium oxide (Merck 1097). By repeated separation on the column, AxE preparation with $E^{1\%}_{1cm}$ value of 634 was obtained and this was employed for the examination after dilution in acetone in a concentration of $E^{1\%}_{1cm}$20. Meanwhile, yellow pigment was saponified by alkali methanol and the unsaponifiable part was collected and repeatedly chromatographed. Tunaxanthin with a $E^{1\%}_{1cm}$ value of 720 thus obtained was used as a test pigment similarly as AxE preparation.

Tissue homogenates were prepared from skin free of flesh or fat, flesh without dark muscle, and liver which was taken from another rockfish (*Sebastes thompsoni*) in good state of freshness. Each of these tissues was homogenized after the addition of five times the volume of M/50 phosphate buffer (pH 6.9) and centrifuged at 8,000 rev/min for 10 min at 0°C (32°F) and the supernatant used as a tissue homogenate.

To a series of test tubes with glass stoppers containing 5 ml of each homogenate was added 5 ml of M/50 phosphate buffer (pH 6.9), 0.5 ml of carotenoid acetone solution, and three drops of an antiseptic mixture of toluene and chloroform consecutively. To the control sample was added 1 ml of 20 per cent KCN solution. These tubes were stored in the dark at temperatures between 7° and 14°C (45° and 57°F).

At each storage period the concentration of the residual carotenoids was determined by extraction using a mixture of 5 ml of ethanol and 10 ml of ethylether. The mixture was shaken occasionally while standing for 1 h and extracted by centrifuge at 3,000 rev/min for 1 min. The spectrophotometric readings were taken at 470 mμ for AxE and 440 mμ for tunaxanthin.

Fig 3 shows a decrease of AxE in the presence of the tissue homogenates during 10 days' storage. It is interesting to note that the skin shows a rapid discolouration, while muscle or liver tissue is almost identical to the skin

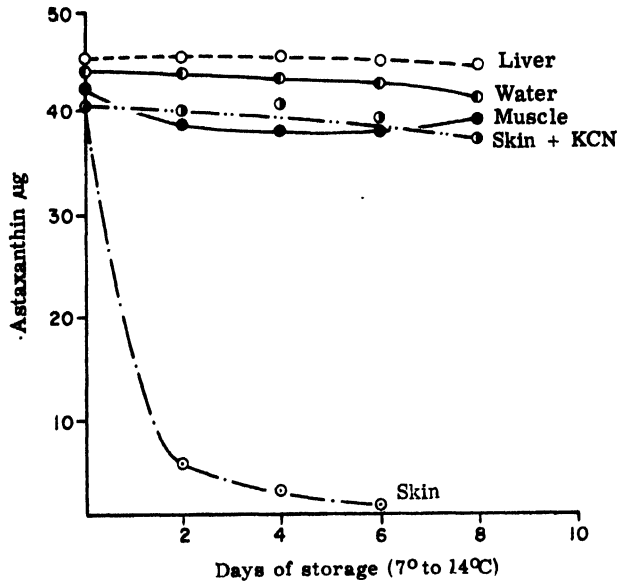


Fig 3. Changes in the concentration of astaxanthin in the presence of the tissue homogenates of a species of rockfish (Sebastes thompsoni) *at 7° to 14°C*

homogenate which has been mixed with potassium cyanide. A similar effect was noted when the pigment was substituted by tunaxanthin as indicated in fig 4. These findings may suggest a possibility of a certain enzymatic action involved in the skin discolouration of rockfish.

Examination of coloured cellophane film as a preventive of astaxanthin discolouration

A concentrate of AxE with $E^{1\%}_{1cm}$ value of 880 was prepared in a similar way as described above from a rockfish (*Sebastiscus marmoratus*) and gurnard (*Chelidonichthys kumu*) and was stored at −20°C (−4°F) until it was used.

A 5 ml sample of AxE was diluted in acetone and placed in a 1 cm diameter test tube and exposed under direct sunlight. Almost complete fading of the colour was noted using either a glass or quartz tube after 20 min exposure and this rate of discolouration was taken as a reference for the examination of coloured cellophane.

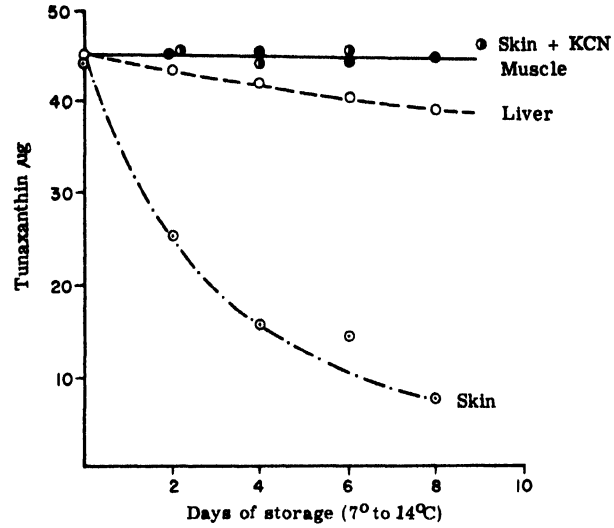


Fig 4. Changes in the concentration of tunaxanthin in the presence of the tissue homogenates of a species of rockfish (Sebastes thompsoni) *at 7° to 14°C*

Commercial cellophane films of violet, blue, green, yellow, pink, tango and red were tested and, in addition, two contra-ultraviolet and one ordinary transparent one were examined. The nature of dyes was not known. These cellophane films were wrapped on a series of test tubes, to each of them was added 5 ml of AxE acetone solution. The exposure tests under direct sunlight at 29°C (84°F), in fig 5, clearly indicate that red cellophane, followed by contra-ultraviolet, is the most effective preventive for pigment discolouration, while pink cellophane is found least effective.

The transmittance curves of the coloured cellophane, shown in fig 6, will substantiate the preventive effect of those observed in fig 5.

Application of the coloured cellophane films to the wrapping of red fish

Typical red fish, red snapper (*Chrysophrys major*), average length of 7 cm and tilefish (*Branchiostegus japonicus*) of 25 cm, were chosen to demonstrate the use

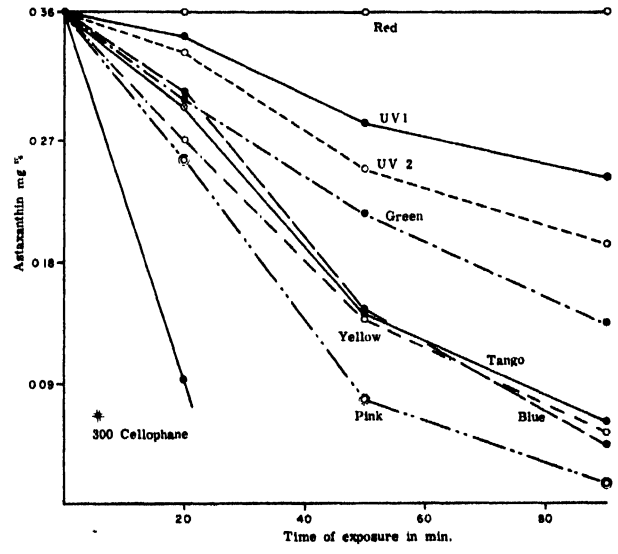


Fig 5. Diminution of astaxanthin in acetone covered with different coloured cellophane under direct sunlight at 29°C

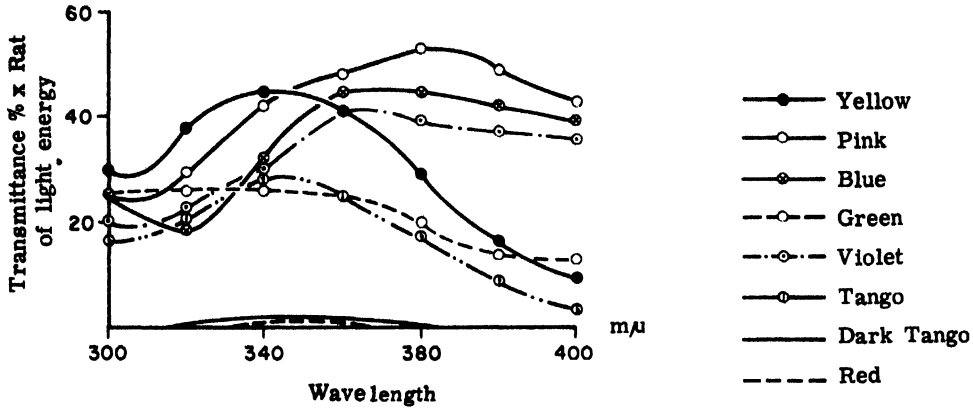


Fig 6. Revised transmittance curves of various coloured cellophane films with average thickness of 0.02 mm, where light energy ratio has been obtained by taking light energy at 300 mμ as 1

of coloured cellophane as a discolouration preventive. The fish were cut from the top dorsal end into symmetrical halves and one half of the fillet was wrapped with the cellophane to be tested and exposed to direct sunlight for 90 min at 27°C (81°F) while the other half was used to determine carotenoid content. The change in terms of the percentage of carotenoid remaining in the skin after exposure is shown in table 1. As expected, red cellophane is very effective.

TABLE 1. QUANTITIES OF CAROTENOID PIGMENTS REMAINING IN THE SKIN OF RED SNAPPERS (CHRYSOPHRYS MAJOR) AND TILEFISH (BRANCHIOSTEGUS JAPONICUS) WRAPPED WITH DIFFERENT CELLOPHANE FILMS BEFORE EXPOSURE UNDER DIRECT SUNLIGHT FOR 90 MIN AT 27°C IN PERCENTAGE OF TOTAL PIGMENTS

Type of cellophane	*Red snapper* (%)	*Tilefish* (%)
Transparent	46.5	44.6
Coloured yellow	60.2	55.1
Coloured red	88.5	92.3
Coloured green	62.0	62.1
Contra-ultraviolet treated	77.3	82.0

SUMMARY

Tuna meat discolouration

Repeated experiments have indicated that more intense discolouration always takes place in the inner tissue than the surface tissue of frozen meat stored between −3° and −10°C (27° and 14°F) for short periods, whereas longer storage tests often show a contradictory result for the rate of discolouration. Since the phenomenon has been quite reproducible, a brief storage test at these temperatures will be useful to analyse the mechanism of tuna meat discolouration.

It is also interesting to note the temperature of maximum discolouration, which differs with the portions. As one cannot find evidence of a biochemical reaction accelerated by freezing between the surface and the inner tissue of the same fish it may be safe to consider some other specific factor that causes the difference.

In the inner tissue the oxygen level could be reduced owing to the remaining residues of tissue respiration, while the surface is surrounded by a higher oxygen partial pressure. Such differences in the oxygen partial pressure will undoubtedly influence the rate of auto-oxidation of myoglobin. Matsuura *et al.* (1962) have reported that myoglobin auto-oxidation reaches a maximum at the point where the pressure is half saturated. This is approximately equivalent to 0.5 mm Hg of oxygen partial pressure at 15°C (59°F) (Matsuura and Hashimoto, 1961), and will become smaller if the temperature is lowered. Oxygen partial pressure in half saturation may have been low under the present experiment and it then could cause the gap between the temperatures of maximum discolouration of the portions.

As for the reason for a slight, but significant, difference in the temperature of maximum discolouration between the surface and inner tissue, no immediate explanation can be given because of the lack of actual measurement of the oxygen partial pressure. After freezing, the balance between oxygen penetration from outside and oxygen consumption by the muscle tissue will become a key whether or not it promotes metmyoglobin formation. Any small variation in oxygen at the surface may not play a big role in the rate of metmyoglobin formation, since a comparatively higher oxygen tension is always available there. Factors other than oxygen partial pressure, such as pH relation, concentration of minerals by freezing and desiccation may be the reason for the surface discolouration. The findings of fig 2 will indicate the effect of lowering oxygen partial pressure provided by a thick ice glaze even at the skin surface.

Various biochemical reactions have been reported at the skin surface that are accelerated at temperatures near that of metmyoglobin. Sharp (1934) described the formation of lactic acid in haddock muscle at −3° to −3.5°C (27° to 25.7°F) and Partmann (1961) reported ATP breakdown at −1.5°C (29°F) in carp or trout muscle, and Bito and Amano (1962) observed it at −1.7°C (29°F) in carp and −2°C (28°F) in horse mackerel muscle. Love and Elerian (1964) noted a marked denaturation of protein in cod at −1.5°C (29°F) and Lovern and Olley (1962) noted that lipid hydrolysis of cod tissue occurred at −4°C (25°F). Matsuura *et al.* (1962) have also reported the acceleration of metmyoglobin formation *in vitro* by lowering the pH or increasing the mineral concentration. It is safe to assume that similar factors produce a surface discolouration between −3° and −4°C (27° and 25°F).

There is probably no significant variation of pH or mineral concentration between the surface of the inner tissue and the main browning factor is probably oxygen partial pressure. But there is no immediate proof to suggest that half saturation of oxygen partial pressure exists at −6° to −7°C (21° and 19°F).

Red fish discolouration

AxE is the largest component in the skin of red fish and Tsukuda and Amano (1966a) reported it not lower than 50 per cent of total carotenoids even in the species considered poor in AxE. AxE contains 11 conjugated double bonds in its structure and consequently is regarded as sensitive to oxidation. Oxidation of AxE could be a major cause of discolouration in red fish. AxE and other carotenoids are normally localized in the skin of fish and are sensitive to the effect of light, oxygen and temperature of their environment.

An increase in discolouration in frozen storage of gurnard at −30°C (−22°F) led the writers to examine the possibility of enzymatic discolouration. A significant activity was discovered in the skin preparation, but the nature of the enzyme has not been confirmed. It is interesting to note from previous observations of the increase in the amount of carotenoids during first two or three days of refrigerated storage of gurnard and rockfish (Tsukuda and Amano, 1966b). No clear evidence has been obtained on the biosynthesis of AxE or tunaxanthin in the homogenates of the tissue of these red fish.

In view of the paucity of light energy in a range shorter than 330 mμ and easy transmittance in the wavelength longer than 330 mμ through a glass tube, the major wavelength affecting the discolouration of carotenoids should be longer than 330 mμ. In the case of coloured cellophane as a discolouration preventive, it was found that this action was proportional to the amount of light at wavelengths from 330 to 380 mμ and particularly between 350 and 360 mμ. However, light longer than 360 mμ may have some discolouring effect since the effect of contra-ultraviolet cellophane which inhibits up to 360 mμ is found to be inferior to red cellophane inhibiting light in a wider range to 580 mμ.

Conclusions

(1) By repeated experiments with short storage times on small cuts of bluefin meat, more metmyoglobin formation was always noted between −3° and −10°C (27° and 14°F) on the inner tissue than at the surface.

(2) A significant difference in the temperature of maximum discolouration was always noted between the inner and surface tissue. The reason for the difference is thought to be due to the relationship between the partial pressure and the accelerating effect due to the changes in pH or salt concentration in the muscle.

(3) A thick ice glaze exerts an adverse effect on the meat colour, possibly due to the inhibition of oxygen penetration, which favours the discolouration under the glaze.

(4) Enzymatic discolouration of astaxanthin or tunaxanthin has been demonstrated in the skin of rockfish; however, the activity seems to be lacking in the flesh and liver.

(5) Light energy may be regarded as the most significant factor in the discolouration during normal storage of red fish. Red-coloured cellophane was found superior as a protective than other coloured or contra-ultraviolet film.

Acknowledgment

The writers wish to express their sincere thanks to Prof. F. Matsuura for his most valuable suggestions.

References

BITO, M *Bull. Jap. Soc. scient. Fish.*, **30**, 847.
1964

BITO, M *Ibid.*, **31**, 534.
1965

BITO, M and AMANO, K *Bull. Tokai reg. Fish. Res. Lab.*, **32**,
1962 149.

LOVE, R M and ELERIAN, M K *J. Sci. Fd Agric.*, **15**, 805.
1964

LOVERN, J A and OLLEY, J *J. Fd Sci.*, **27**, 551.
1962

LUSK, G, KAREL, M and GOLDBLITH, S A *Fd Technol.*,
1964 *Champaign*, **18**, 157.

MATSUURA, F and HASHIMOTO, K *Bull. Jap. Soc. scient. Fish.*,
1961 **27**, 162.

MATSUURA, F, HASHIMOTO, K, KIKAWADA, M and YAMA-
1962 GUCHI, K *Ibid.*, **28**, 210.

PARTMANN, W *Z. ErnährWiss.*, **2**, 70.
1961

SHARP, J G *Rep. Fd Invest. Bd*, HMSO, London, 96 pp.
1934

TSUKUDA, N and AMANO, K *Bull. Jap. Soc. scient. Fish.*, **32**,
1966a 334.

TSUKUDA, N and AMANO, K *Ibid.*, **32**, 522.
1966b

YAMAGA, M and MORIOKA, K *Ibid.*, **28**, 1104.
1962

DISCUSSION

Sidhu (Australia): Hansen and his colleague have presented an excellent review paper on the freezing of shellfish. I would like to make some observations on the basis of the work which we have done in Australia on the freezing of crayfish (*Jasus lalandii*). It was observed that for storage periods of up to 12 months at −20°C (−4°F), organoleptically better results are obtained by freezing green crayfish tails than by freezing whole green or whole cooked crayfish. Crayfish frozen whole, in green or cooked form, are likely to go "mushy" to a varying degree, starting from the butt end of the tail. I would like to know if someone could throw further light on the development of this defect in frozen crayfish. Preliminary observations indicate that *rigor mortis* is not a clearly defined event in crayfish. Although there is a rapid breakdown of glycogen arginine phosphate and other phosphorylated intermediates, accompanied by the production of lactic acid yet, unlike mammalian muscle, the pH does not show a proportional fall and the muscle does not show clear-cut shortening.

Perez-Garcia (Spain): En relación con la denominación de los moluscos, queremos indicar que el término *Cephalopodos* es incorrecto y en el Congreso Mundial de Zoologia celebrado en Madrid 1960 se acordó que el término correcto es el de *Sifonopodos* o *Siphonopodos* por razones de tipo científico ante los avances realizados por los estudios embriológicos.

Darghouth (Tunisie): L'auteur préconise en quelque sorte aprés congélation "d'emprisonner" les produits dans un pain de glace. Cette opération est elle réalisable dans la pratique? Cette même opération est elle économiquement viable: (a) pour le transport; (b) pour l'entreposage?

Vyncke (Belgium): I would like to give some very brief comment on the methods described by Hansen and Aagaard to prevent dehydration and oxidation of frozen shellfish and more particularly of Norway lobster (*Nephrops norvegicus*). Processors generally prefer not to glaze cooked Norway lobsters after freezing as it is a so-called dry product and water may badly influence quality. However, our experiments show that there is no objection to thoroughly glaze the lobsters. Upon thawing, of course, a certain amount of liquid is set free, but a short period of drying is sufficient to give a product which is markedly better than unglazed lobsters.

Aagaard (Denmark): I should like to comment on the investigations of Amano *et al.* concerning the discolouration of carotenoid pigments from rockfish. At our laboratory, we are interested in similar problems in connection with the freezing preservation of deep-water shrimp (*Pandalus borealis*). The pigment in these red shrimps is mainly astaxanthin, the colour of which normally fades and eventually turns orange to yellow during frozen storage of whole shell-on shrimps. In our investigations, we started with the assumption that the colour changes are mainly caused by normal oxidation reactions, and we are carrying out experiments on the possible protection against discolourations by anti-oxidant treatment.

However, an interesting observation has been made, which may be connected with the authors' suggestion that enzymatic action is possibly involved in the skin discolouration of rockfish. We have found that shrimps, which have been cooked prior to freezing and thus have had their enzymes destroyed are much less susceptible to colour changes, especially to fading, during frozen storage, than shrimps which have been frozen raw and heat-treated after thawing. I could find two possible reasons for this observation. The first is connected with the authors' suggestion that enzymes may be the cause of the changes. The second possibility could be that the pigments, or part of them, are more stable after cooking. In shrimp, the red pigment is believed to be mainly an ester of palmitic acid, which is red in the natural form. On cooking, however, there is a minor colour increase (about 25 per cent) as measured by spectrophotometric readings on acetone extracts. This means that some changes occur during cooking.

Would the authors, who have done much work on related problems, please comment on this. Do they think that fading of the red colour and the changing from red to yellow could possibly be caused by two different reactions, the first possibly being enzymatic and the second purely oxidative? The background of the latter question is that a marked fading of the red colour of raw frozen shrimp takes place after one week's storage at $-25°C$ ($-13°F$), while the yellow colours develop in about six months of frozen storage.

Amano (Japan): Major cause of colour fading in red fish could be chemical oxidation under storage condition of the fish held in ice. However, the discolouration in frozen storage can be better explained by the action of a newly discovered enzyme contained in the skin tissues, since chemical oxidation should be fairly well arrested under frozen storage and in darkness.

Effect of Brining and Polyphosphate on Yield and Quality

by W. J. Dyer

Effect of brining and polyphosphate on yield and quality

A revival of interest in the thaw drip which forms on thawing frozen tissue because of loss of water-binding capacity of the protein has promoted further study of various salts for its control, particularly polyphosphates in addition to sodium chloride brine and other phosphates. Data on the effectiveness of these compounds for the reduction of drip are reviewed, including the changes on frozen storage, and their use in refrozen fish products.

Thaw drip increases initially during frozen storage with time and with higher storage temperatures, then reaches a plateau and may slowly decline if desiccation occurs during storage. Combination of brine and polyphosphate is more effective for drip reduction than either alone in some products. The most important effect of such treatment may be the considerable increase in yield of both frozen and thawed products, due to initial absorption of dipping solution coupled with subsequent possible reduction of thaw drip in comparison with a greater loss of thaw drip alone in the undipped control. Polyphosphates may act by promoting dissociation of the actomyosin complex, though penetration may be insufficient for this to be effective beyond the surface layers. Most present evidence indicates little detectable effect on quality other than in improved appearance and juiciness. Extractable protein or free fatty acid are apparently unaffected, as is taste and in most cases texture.

Effet du saumurage et du traitement au polyphosphate sur la qualité et le rendement du produit

Un renouveau d'intérêt pour l'exsudation causée par la décongélation des tissus congelés par suite d'une perte de la capacité de rétention d'eau de la protéine a donné une impulsion ultérieure à l'étude des différents sels pouvant être utilisés pour empêcher ce phénomène. On a notamment étudié l'addition des polyphosphates et d'autres phosphates à la saumure de chlorure de sodium. Les données relatives à l'action de ces composés sur le réduction de l'exsudation sont examinées, en particulier les modifications en cours d'entreposage sous congélation et l'utilisation des phosphates dans les produits de la pêche recongelés.

L'exsudation à la décongélation augmente initialement au cours del 'entreposage sous congélation, en fonction du temps et de l'augmentation de la température d'entreposage, puis elle devient constante et peut ensuite décroître lentement si la dessiccation se manifeste pendant l'entreposage. Une combinaison saumure/polyphosphates réduit plus efficacement l'exsudation que l'une ou l'autre de ces deux substances utilisées séparément. La conséquence la plus importante de ce traitement pourrait être l'augmentation considérable de la quantité aussi bien des produits congelés que des produits décongelés, grâce à l'absorption initiale de la solution de trempage, qui provoque la diminution de l'exsudation à la décongélation; le témoin non trempé, au contraire, subit une plus grande perte par exsudation. Les polyphosphates agissent vraisemblablement en provoquant la dissociation du complexe actomyosine, bien que la pénétration ne suffise peut-être pas à provoquer ce phénomène au-dessous des couches superficielles. Les effets secondaires de ce traitement sur la qualité—outre l'amélioration de la qualité et de l'aspect du produit—sont insignifiants. La protéine extractible et l'acide gras libre ne semblent pas avoir été affectés et il en est de même pour le goût et, dans la plupart des cas, pour la texture.

El efecto del salmuerado y los polifosfatos en el rendimiento y en la calidad

El renacimiento del interés por el exudado que se produce al descongelarse los tejidos, debido a la pérdida de la capacidad de retención de humedad de las proteínas, ha estimulado la realización de nuevos estudios de varias sales para impedir tal exudado, especialmente los polifosfatos combinados con salmuera de cloruro de sodio y otros fosfatos. Se examinan los datos sobre la eficacia de estos compuestos para la reducción del exudado, incluyendo los cambios en el almacenamiento frigorífico, y su empleo en los productos pesqueros recongelados.

Durante el almacenamiento frigorífico, el exudado en la descongelación aumenta inicialmente con el tiempo y con el aumento de las temperaturas de conservación; después se detiene y empieza a disminuir lentamente si se produce desecación. La combinación de salmuera y polifosfato es más eficaz que uno u otro de ambos para la reducción del exudado en ciertos productos. El efecto más importante de tal tratamiento es posible que sea un considerable aumento en el rendimiento de productos tanto congelados como descongelados, debido a la absorción inicial de solución de inmersión junto con la posible reducción posterior del exudado que se produce durante la descongelación, en comparación con una mayor pérdida de exudado en la descongelación del testigo que no fue objeto de baño de inmersión. Los polifosfatos pueden actuar favoreciendo la disociación del complejo de actomiosina, aunque es posible que la penetración sea insuficiente para producir efectos más allá de las capas superficiales. Casi todos los datos de que se dispone indican pocos efectos detectables en la calidad, exceptuada la mejora del aspecto y la jugosidad. Al parecer las proteínas extraibles o los ásidos grasos libres no se ven afectados, como lo son el gusto y, casi siempre, la textura.

WITH the increasing processing of fish at sea, freezing of *pre-rigor* whole and filleted fish on the boat and at shore establishments and of frozen blocks for manufacture of fish sticks and similar cooked or partially cooked products there is an increasing interest in moisture losses in fresh and iced fish and especially in "thaw-drip" following defrosting of frozen packs.

This loss of moisture-holding capacity is a natural phenomenon resulting from a decrease in water-binding capacity of the muscle proteins occurring *post-mortem* and on frozen storage. The changing ionic environment and the usual strong shift to pH to more acid conditions, changes resulting from *post-mortem* glycolysis, degradation of "high energy phosphorus" containing nucleotides, as well as formation of the actomyosin protein complex, favour reduced moisture binding and weep or drip occurs. As fish muscle proceeds into *rigor*, the previously firm and dry surface becomes wet and moisture is seen to exude. At this stage also the cells' supply of high energy compounds necessary for maintenance of cell membranes becomes depleted and the membranes become permeable to water and salts, thus allowing the excess water no longer bound by the proteins to escape. It is thus not necessary to postulate that the cells have to be cut open or mechanically disrupted to allow escape of moisture.

Subsequent aggregation or denaturation of protein during frozen storage also reduces its affinity for water. Freezing out of water concentrates the salts present, possibly changes pH and dehydrates the normally highly hydrated and organized array of protein molecular chain

structure. As ice melts during thawing, the original structure is only partially reformed and usually excess water remains to form "thaw-drip". Hence, there has been a renewed interest in methods for control of drip in iced and in thawed fish, especially the use of brine and various phosphates.

The present state of knowledge and areas of its deficiency of the various factors affecting drip formation have been reviewed by Miyauchi (1964) and will not be discussed here.

DRIP LOSS IN ICED FISH

In fish iced on board vessels or for holding on shore, drip formation losses vary with time, species, season, size of fish, pressure and handling conditions but may often be 5 to 10 per cent in a week's storage (Castell, 1966). In gutted cod (*Gadus morhua*) iced on the vessel for a week or so Ellison (1934) notes losses up to 8 per cent, though Holston (1966) indicates losses as high as 18 per cent. Young (1941) finds 5 to 12 per cent loss in halibut (*Hippoglossus stenolepis*) in 11 days but only 2 to 4 per cent in salmon (*Oncorhynchus* spp.). In extreme cases, contraction of the muscle may occur and drip losses may be still higher as sometimes found in processing trap-caught cod in warm weather and under poor handling conditions (Dyer and Fraser, 1961; Jones, 1965). During processing water may be picked up by the fillets during washing, conveying by flumes, etc., and this is subsequently gradually released, mainly within 24 h, often as pockets in the package while awaiting freezing unless care is taken to avoid delay between packaging and freezing (Castell, 1966; Dyer, 1960).

THAW-DRIP IN THAWED FROZEN PRODUCTS

Various factors influence the degree of thaw-drip. These may be inherent in the fish used, pre-freezing treatment, manner of freezing and storage conditions, and conditions during thawing. Under good conditions, thaw-drip is usually less than 10 per cent but may be considerably higher after long storage or under poor conditions. Refreezing also greatly increases the amount of drip, e.g. in one experiment, cod once frozen showed 9 per cent thaw-drip, while samples of the same lot averaged 17 per cent after refreezing (Dyer *et al.*, 1962).

In recent experiments (Dyer, Fraser and MacCallum (MS), 1967) it has been found that a considerable increase in thaw-drip in fillets of American plaice (*Hippoglossoides platessoides*) occurs during early frozen storage. The data of Good and Stern (1955) on English sole (*Parophrys vetulus*) show a similar rapid increase in thaw-drip of about the same magnitude after one to two weeks following freezing to between six weeks and three months' storage at −18°C (0°F). Their data also show a consistent increase when the fish used were more than one day in ice prior to being frozen, the drip values being maximum at about six days on ice.

Notevarp and Heen (1940) concluded that free flowing drip did not correlate well with quality changes on frozen storage; they preferred to use the total of free and "press" drip. However, a plot of their data (fig 1) for storage at −20°C (−4°F) for "fresh" and three-day iced

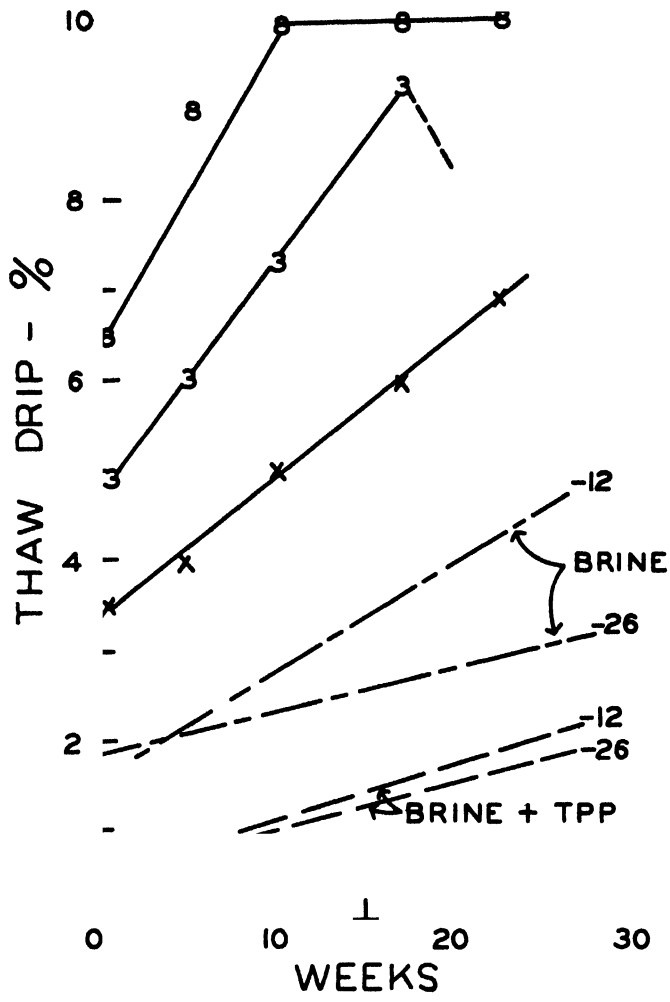


Fig 1. Thaw drip (free) in frozen cod stored at −20°C in samples fresh (X), *stored three days in ice* (3), *and eight days in ice* (8) *prior to freezing; values for freezing times of ¼, ½ and 8 h are averaged—data from Notevarp and Heen (1940). Regression lines for thaw-drip in cod dipped prior to freezing in brine or in a brine+TPP mixture, storage at −12°C and at −26°C—data from Dyer, Fraser and MacCallum (1967)*

cod (data for freezing times ¼, ½ and 8 h averaged) shows a steady increase in free drip up to at least 20 weeks. The amount is considerably higher after three days in ice than in *pre-rigor* frozen fish and higher still in the fish frozen after eight days in ice, though the latter samples level off at about 10 per cent after 10 weeks. In these samples it appears likely that the arrest of the increasing trend with subsequent drop in drip values was due to drying out of the samples (waxed-paper wrapped) especially in those stored at −9°C (16°F). This drying out on storage was observed in waxed-paper wrapped cod (MacCallum *et al.*, 1964a). Similar increases in thaw-drip were obtained in South African hake (*Merluccius capensis*) stored at −12°C (10°F) up to about three months, although apparently dehydration occurred in some if not all samples at and after this period (Pienaar and Thomas, 1964).

Summarizing the data, it appears that the amount of thaw-drip increases during the early part of the frozen storage period and subsequent changes will be influenced strongly by dehydration. In addition, decreased freshness,

measured by increased time in ice prior to freezing, also augments strongly the amount of drip.

Besides being messy, such drip losses result in loss of weight, protein, minerals and flavour.

Cooking of packaged fish without prior thawing is sometimes used to bypass the problem but the more usual solution is to treat the fish prior to freezing in a sodium chloride or phosphate brine.

CONTROL OF THAW-DRIP

Brine

Sodium chloride brine dips have long been used to reduce thaw-drip. Representative data on haddock (*Melanogrammus aeglefinus*) fillets (Holston and Pottinger, 1955) indicate use of about half saturated brine is necessary although some effect is obtained at lower concentrations. Actomyosin swells very strongly absorbing salt and water in solutions of 0.5 to 1 M NaCl (Duerr and Dyer, 1952; Hamm, 1963; Tarr, 1942; Wierbicki, Cahill and Deatherage, 1957) and thaw drip is a minimum in ground beef at an ionic concentration of 0.5 while at the pH of fish muscle, thaw-drip is a minimum at about 1 per cent salt (Holston and Pottinger, 1955; Tarr, 1942). Sodium chloride, however, has a tendency to accelerate rancidity on storage resulting in off-odour and off-flavour development in many species, and for this reason its use is declining.

It has recently been pointed out (Dyer *et al.*, 1964) that brining, as well as phosphate dips, result in considerable improvement of yield of both frozen and of thawed product, because of a 1 to 5 per cent absorption of dip solution combined with the thaw-drip reduction obtained.

Polyphosphate and other phosphates

Various phosphates from orthophosphates, through pyrophosphate, tripolyphosphate (TPP) to the high molecular weight glassy phosphates or metaphosphates have been used to improve moisture retention in various food products. Hellendoorn (1962) reviews their use concluding that tripolyphosphate and pyrophosphate are the most effective compounds when used in combination with salt at the proper ionic concentration and pH.

The specific effect of pyrophosphate, adenosine triphosphate (ATP) and TPP on swelling and on moisture retention after cooking (Bendall, 1954; Hellendoorn, 1962) is attributed to splitting of actomyosin into myosin and actin, TPP having a structure similar to ATP. This dissociation may also be brought about by increasing the ionic concentration to 1 to 1.5 by NaCl or other salts (Ellis and Winchester, 1959), but this concentration of course is too high for a food product. Hellendoorn shows that additional salt to raise the ionic concentration to about 0.35 or above for pyrophosphate and 0.4 to 0.6 with TPP is necessary to obtain the specific extra phosphate effect on swelling and moisture retention in cooked meat.

For thaw-drip inhibition in fish, Mahon (1962) obtained a patent using TPP and presents data for solution uptake and thaw drip in haddock finding the thaw-drip lower than in water-dipped controls. Using 7.5 to 12.5 per cent dips of sodium-TPP uptakes of 0.2 to 0.4 per cent were obtained in the presence or absence of 4 per cent salt. The ionic strength was not sufficiently high to obtain more effective drip control than by salt alone (Dyer *et al.*, 1964), the effect obtained being comparable to half-saturated NaCl brine drips.

Using paired fillets of cod little difference in thaw-drip of TPP-treated fillets as compared to undipped controls was found by Dyer *et al.* (1964): pick-up of water in water-dipped controls (Castell, 1966) would result in more thaw-drip than undipped controls (considerable draining occurs in commercial conditions) resulting in higher apparent effectiveness of TPP. Considerable differences were found in uptake of dip solution which varied from 2 to 9 per cent in fillets from six fish; this is probably the reason for use of batch-type treatment in industry rather than passing through a brine tank on a continuous belt. In some species, Dover sole (*Microstomus pacificus*), Pacific cod (*Gadus macrocephalus*), halibut (*Hippoglossus stenolepis*) and red snapper (*Sebastodes ruberrimus*) TPP was effective in reducing thaw-drip in comparison with water-dipped controls but was not effective in others, e.g. chinook salmon (*Oncorhynchus tschawytscha*) (Boyd and Southcott, 1965). In refrozen cod (MacCallum *et al.*, 1964), TPP was effective only when the fish were treated between freezings and not before the first freezing, although yields were improved as discussed below. In some lots of electronic-thawed cod, showing low drip in control fish, 1 to 2.5 per cent, TPP-treated fish were somewhat lower, about 1 per cent (MacCallum, 1964a). Further work (Chalker, MacCallum and Idler, 1965) compared different methods of measuring thaw-drip, showing large variations between samples especially the TPP-treated ones. The latter gave about 23 per cent less drip on average in fish frozen one to two weeks.

The combination of brine and TPP at ionic strengths sufficiently high to promote actomyosin dissociation (see Dyer *et al.*, 1964) has recently been tested and found to be more effective than brine alone. With South African hake, Pienaar and Thomas (1964) found after one month at −12°C (10°F), TPP treatment reduced thaw-drip to about 3 per cent from 10 per cent for untreated control (14 per cent in water-dipped control); a half-saturated NaCl dip gave 2 per cent thaw-drip but the combination of half-saturated NaCl followed by TPP was still more effective reducing thaw-drip to about 1 per cent. In work being prepared for publication (Dyer, Fraser and MacCallum, 1967), half-saturated brine was compared with a dip in a mixture of half-saturated brine plus half-saturated TPP on cod fillets. Uptake of dip was very variable but greater in the mixed dip. In these samples thaw-drip levels were low initially, about 1.5 per cent, and while levels increased on storage, the mixed dip treatment resulted in considerably less thaw-drip than brine alone.

YIELD OF FROZEN AND OF THAWED PRODUCT

Perhaps the greatest advantage in using brine or phosphate treatment is the increase in yield of frozen, thawed and perhaps also of cooked product (Dyer *et al.*, 1964). Yield of frozen product will be higher in the dipped samples by the amount of dip absorbed. With half-saturated brine (20 sec dip) this absorption is about 2 to 5 per cent in haddock (Holston and Pottinger, 1955) and

in cod (Dyer, Fraser and MacCallum, 1967) about 4 per cent in Pacific cod and 3 per cent in halibut and in Pacific salmon (Boyd and Southcott, 1965). TPP dips added roughly similar amounts (Boyd and Southcott, 1965; Dyer *et al.*, 1964; Mahon, 1962), and again the uptake was very variable, even in fillets of the same size and from the same lot of fish. In most cases the thaw-drip from brined and TPP-treated fish is nearly equal to the amount of dip solution absorbed (Boyd and Southcott, 1965; Dyer *et al.*, 1964), and thus the yield of thawed product is near 100 per cent of the freshly filleted fish. Without treatment, of course, thawed yield will be less by the amount of thaw-drip, and consequently is much less than from treated fish.

Both TPP and hexametaphosphate reduced total weight loss after cooking in Dover sole although not in Pacific salmon (Boyd and Southcott, 1965). It is commonly thought that this retention of thaw-drip and reduction of cooking losses results in a juicier product and it has been reported to result in improved appearance.

QUALITY

Apart from juiciness associated with moisture retention, lessening of a dried out appearance and of loss of nutrients, salts, flavour, etc., in the drip, the possible effect on storage quality must be considered. If actomyosin dissociation occurs, and/or sequestration of Ca or other metals is involved, then the stability of the protein during frozen storage may be altered. Similarly, the antioxidant effect of the metal sequestration may affect lipid oxidation. No effect due to TPP, on taste or texture assessment, on free fatty acid formation or extractable protein was detected in frozen cod on storage at −12°C (10°F) or at −26°C (−15°F) (Dyer *et al.*, 1964, 1967; MacCallum *et al.*, 1964a, 1964b). The latter authors also find similar protein electrophoretic patterns in TPP-treated and control fish but a slightly higher texture score was found in the treated samples in one experiment. Somewhat erratic extractable protein values in the TPP samples in our later work (Dyer, Fraser and MacCallum, 1967) may possibly also indicate modification by the TPP. Both Tanikawa, Akiba and Shitamori (1963) and Ohta and Nichimoto (1963) consider that protein denaturation in minced muscle may be slowed in the presence of TPP. It seems that the effect, if present, may not be very important. As regards the antioxidant effect, results were negative with Pacific salmon (Boyd and Southcott, 1965) although reported to be positive in meats (Ramsey and Watts, 1963; Tims and Watts, 1958), especially in chicken (Tod, 1966). Various investigators have shown that although TPP is rather alkaline, it has very little effect on tissue pH in the concentrations used (Boyd and Southcott, 1965; Ohta and Nichimoto, 1963).

It is considered that in the presence of enzymes and acid digestive juices that the various polyphosphates will be in large part hydrolysed to orthophosphates and thus their use is not regarded as a health problem (Tod, 1966). The uptake of TPP is reported by only a few authors: in haddock Mahon (1962) found about 0.2 to 0.4 per cent expressed as Na-TPP (25 per cent P) and in cod uptake was 0.2 to 0.5 per cent (Dyer *et al.*, 1964; MacCallum *et al.*, 1964b). The rate of penetration of phosphate is not known although Kuusi *et al.* (1966) found a very slow diffusion of pyrophosphate containing P^{32} into stored herring (*Clupea harengus*) fillets. Presumably little diffusion would take place in frozen storage at low temperatures where very little free liquid is present. In flesh, diffusion of salt is rather slow, one to two days being required for NaCl to reach the centre of a 5 cm (2-in) thick cod (Dyer, 1942) but the release of water on thawing should lead to more rapid equilibration. Possibly some enzymic hydrolysis of TPP to pyrophosphate and orthophosphate as found in muscle extracts (Mackie, 1966) may also occur in the tissue although this has not been measured in fish muscle.

CONCLUSIONS

TPP and brine do increase yield of frozen and of thawed product. They also decrease thaw-drip and associated losses. Brine at a reasonably high concentration increases the effectiveness of TPP.

There appears to be a minimum effect on texture and taste of the cooked product, and on storage life of the frozen pack, although brine may sometimes accelerate rancidity and TPP may sometimes inhibit it.

Remaining problems are the large variation in uptake especially with TPP which results in non-uniformity with continuous brining systems.

References

BENDALL, J R 1954 The swelling effect of polyphosphates on lean meat. *J. Sci. Fd Agric.*, **5**, 468.

BOYD, J W and SOUTHCOTT, B A 1965 Effect of polyphosphates and other salts on drip loss and oxidative rancidity of frozen fish. *J. Fish. Res. Bd Can.*, **22**, 53.

CASTELL, C H 1966 Gain and loss in the weight of fillets during processing and storage. *New Series Circular*, No. 27, Fisheries Research Board of Canada, p. 1.

CHALKER, D A, MACCALLUM, W A and IDLER, D R 1965 Studies on the quality of Newfoundland cod. II. Thaw-drip in polyphosphate-treated and untreated fillets. *J. Fish. Res. Bd Can.*, **22**, 783.

DUERR, J D and DYER, W J 1952 Proteins in fish muscle. IV. Denaturation by salt. *Ibid.*, **8**, 325.

DYER, W J 1942 The salting of codfish. *Prog. Rep. Atlant. Cst Stns*, **32**, 6.

DYER, W J 1960 "Wet" frozen fish blocks. *Trade News*, Department of Fisheries, Canada, **13**(5), 8.

DYER, W J and FRASER, D I 1961 Moisture in fish blocks processed from very fresh fish. *Can. Fisherm.*, **48**(8), 17.

DYER, W J, FRASER, D I and MACCALLUM, W A (MS.) 1967

DYER, W J, FRASER, D I, ELLIS, D G, IDLER, D R, MACCALLUM, W A and LAISHLEY, E 1962 Quality changes in stored refrozen cod fillets. *Annex 1962-1 Bull. int. Inst. Refrig.*, 515–524.

DYER, W J, BROCKERHOFF, H, HOYLE, R J and FRASER, D I 1964 Polyphosphate treatment of frozen cod. I. Protein extractability and lipid hydrolysis. *J. Fish. Res. Bd Can.*, **21**(1), 101.

ELLIS, D G and WINCHESTER, P M Proteins in fish muscle. 12. 1959 Ultracentrifuge studies on *post rigor* extracts of structural protein. *Ibid.*, **16**, 33.

ELLISON, W A Prevention of spoilage at sea. II. The hold. 1934 *Fishg Gaz.*, April, p. 17.

GOOD, C M and STERN, J A The effects of iced and frozen 1955 storage upon the trimethylamine content of flounder (*Porophrys vetulus*) muscle. *Fd Technol., Champaign*, **9**, 327.

HAMM, R The water imbibing power of foods. In *Recent* 1963 *Advances in Food Science*, ed. Leitch and Rhodes, Butterworth, London, p. 3.

HELLENDOORN, E W Water-binding capacity of meat as 1962 affected by phosphates. *Fd Technol., Champaign*, **16**, 119.

HOLSTON, J A Research in review. *Fishg Gaz.* **83**(12), 11. 1966

HOLSTON, J A and POTTINGER, S R Brine dipping of haddock 1955 fillets. *Comml Fish. Rev.*, **17**(10), 21.

JONES, N R Problems associated with freezing very fresh fish. 1965 In *Fish Handling and Preservation*, OECD, Paris, p. 31.

KUUSI, T, NIKKILA, O E and KYTŐKANGAS, R Changes in fish 1966 protein in freezing and their inhibition with phosphates. *Kulde*, **19**, 128. Cited in Abst. 16373, *Bull. int. Inst. Refrig.*, **46**, 640.

MACCALLUM, W A, SHIEH, H S, CHALKER, D A, DYER, W J 1964a and IDLER, D R Polyphosphate treatment of frozen cod. 2. Effect on drip, yield, lipid hydrolysis and protein extractability in twice-frozen Newfoundland summer trap and fall cod. *J. Fish. Res. Bd Can.*, **21**, 539.

MACCALLUM, W A, CHALKER, DOROTHY A, LAUDER, J T, 1964b ODENSE, P H and IDLER, D R Polyphosphate treatment of frozen cod. 3. Taste panel evaluation, chemical assessment, and thaw drip in once-frozen Newfoundland trap-caught cod. *Ibid.*, **21**(6), 1397.

MACKIE, I M The effect of adenosine triphosphate, inorganic 1966 pyrophosphate and inorganic tripolyphosphate on the stability of cod myosin. *Biochim. biophys. Acta*, **115**, 160.

MAHON, J H Preservation of fish. U.S. Patent 3,036,923, 1962 29th May.

MIYAUCHI, D T Drip formation in fish. I. A review of factors 1964 affecting drip. *Fishery Industrial Research*, U.S. Bureau of Commercial Fisheries, **2**(2), 3.

NOTEVARP, O and HEEN, E Über den Einfluss der Gefrier- 1940 geschwindigkeit, der Lagertemperatur und der Frische des Rohmaterials auf die Qualität gefrorener Fische. *Z. ges. Kälteind.*, **47**, 122–126, 140–142.

OHTA, F and NICHIMOTO, J Preventive effect of polyphosphate 1963 on the drip-formation of the thawed fish flesh. *Mem. Fac. Fish. Kagoshima Univ.*, **12**, 14.

PIENAAR, A G and THOMAS, K J Drip from frozen hake fillets 1964 on thawing. *17th Annual Report 1963*, Fishing Industry Research Institute, Cape Town, p. 15.

RAMSEY, M B and WATTS, B M The antioxidant effects of 1963 sodium tripolyphosphate and vegetable extracts on cooked meat and fish. *Fd Technol., Champaign*, **17**, 102.

TANIKAWA, E, AKIBA, M and SHITAMORI, A Cold storage of 1963 cod fillets treated with polyphosphates. *Ibid.*, **17**, 1425.

TARR, H L A Effect of pH and NaCl on swelling and drip in 1942 fish muscle. *J. Fish. Res. Bd Can.*, **5**, 411.

TIMS, M J and WATTS, B M Protection of cooked meats with 1958 phosphates. *Fd Technol., Champaign*, **12**, 240.

TOD, C W Phosphates as food modifiers. *J. Fd Technol.*, 1966 **1**(2), 13.

WIERBICKI, E, CAHILL, V R and DEATHERAGE, F E Effects of 1957 added sodium chloride, potassium chloride, calcium chloride, magnesium chloride, and citric acid on meat shrinkage at 70°C and of added sodium chloride on drip losses after freezing and thawing. *Fd Technol., Champaign*, **11**, 74.

YOUNG, O C Thawing of fish. II. *Prog. Rep. Pacif. Cst Stns*, 1941 **50**, 16.

Polyphosphate Treatment of Cod Muscle

by A. H. Sutton

(with addendum by A. H. Sutton and J. I. W. Anderson—
Bacterial contamination of fillets due to polyphosphate dipping)

Polyphosphate treatment of cod muscle

Despite the considerable volume of work reporting the use of polyphosphates in foodstuffs, there is still considerable doubt as to its effectiveness in improving the quality of fish. This paper reports on experiments designed to clarify the situation.

Two polyphosphates were investigated, sodium tripolyphosphate (TPP) and sodium pyrophosphate (PP). In all cases TPP gave the most satisfactory results.

From a systematic investigation into the variables which might effect the process it has been shown that polyphosphate has a two-fold action.

(1) It reduces the fluid lost on thawing frozen fillets. This is of economic importance.

(2) The increased water retention improves the textural properties of the cooked muscle.

Drip losses ranging from 12 to 24 per cent were found with *pre-rigor* unprocessed fish. These then remained fairly constant at between 2 and 10 per cent up to the six days on ice studied. The same pattern of results was obtained with the treated fish, although drip losses were now considerably reduced, and in many cases an increase in weight occurred. Fluid retention increased with time of dipping but not with concentration of dip above 6 per cent TPP.

It was found, however, that the conditions which gave maximum fluid retention produced fish with unacceptable flavours. Some preliminary results showed that a very light treatment with TPP (4 per cent solution for 0.5 min) gave improved water retention and texture, and this was confirmed by larger scale experiments. From this it was found that both high and low pH fish had improved water retention properties but only the low pH fish showed a change in texture. Additions of sodium chloride did not produce any improvement over phosphate alone.

It is evident from these experiments that treatment of cod muscle under suitable conditions can improve the water retention and quality of cod fillets.

Traitement au polyphosphate du muscle de morue

Malgré la vaste littérature actuelle sur l'utilisation des polyphosphates dans l'industrie alimentaire, leur efficacité quant à l'amélioration de la qualité du poisson est encore très discutée. Le présent document rend compte d'un certain nombre d'expériences effectuées pour éclaircir la situation à ce sujet.

Deux polyphosphates ont été étudiés, le tripolyphosphate de sodium (TPP) et le pyrophosphate de sodium (PP). Dans tous les cas examinés, c'est le TPP qui a donné les résultats les plus satisfaisants.

Grâce à une étude systématique des variables pouvant affecter le processus, on a pu constater que les polyphosphates ont une action double.

(1) Ils réduisent la perte de fluide à la décongélation des filets congelés. C'est là un facteur important du point de vue économique.

(2) L'augmentation de la capacité de rétention d'eau améliore la texture de la chair après cuisson.

Des poissons non traités avaient subi avant l'établissement de la rigidité, des pertes à l'exsudation variant de 12 à 24 pour cent, qui se sont maintenues assez constantes entre 2 et 10 pour cent pendant les six jours dans la glace que comportait le test. Des résultats analogues ont été obtenus avec des poissons traités, bien qu'on n'ait pas obtenu une réduction considérable des pertes à l'exsudation, et dans plusieurs cas, on a pu constater une augmentation de poids. La rétention de fluide s'est accrue avec la durée du trempage mais non pas lorsqu'on a augmenté la concentration de TPP dans la solution de trempage au-dessus de 6 pour cent.

On a constaté cependant que les conditions permettant une rétention maximale de fluide finissent par donner un produit ayant un goût inacceptable. Quelques résultats préliminaires indiquent qu'un traitement avec un très faible pourcentage de TPP pendant un temps très court (solution à 4 pour cent pendant 0.5 min) améliore la rétention d'eau et la texture. Cette conclusion a été confirmée par une série d'expériences effectuées sur une vaste échelle. Ces expériences ont également permis de constater que les poissons à pH élevé ou faible ont une meilleure capacité de rétention d'eau, mais que seuls les poissons à faible pH subissent une modification de la texture. L'addition de chlorure de sodium n'a pas été plus efficace que la seule addition de phosphate.

Ces expériences ont fourni la preuve que le traitement du muscle de morue dans des conditions appropriées peut améliorer la capacité de rétention d'eau des filets de poisson et par conséquent leur qualité.

El tratamiento con polifosfato de la carne de bacalao

A pesar de la considerable cantidad de trabajos que tratan del empleo de los polifosfatos en los alimentos, existen todavía, sin embargo, muchas dudas acerca de su eficacia para mejorar la calidad del pescado. En esta comunicación se dan a conocer los experimentos realizados para aclarar la situación.

Se investigaron dos polifosfatos, el tripolifosfato de sodio (TPF) y el pirofosfato (PF) de sodio. En todos los casos el TPF fue el que dio los resultados más satisfactorios.

Una investigación sistemática de las variables que podrían influir en el proceso ha demostrado que el polifosfato ejerce una doble acción:

(1) Reduce la pérdida de fluidos al descongelar los filetes congelados. Esto tiene importancia económica.

(2) La mayor retención de humedad mejora las propiedades y la textura de la carne cocinada.

Se encontraron antes de la rigidez pérdidas por exudado del 12 al 24 por ciento. En el pescado sin tratar estas pérdidas se mantuvieron bastante constantes entre el 2 y el 10 por ciento hasta los seis días de almacenamiento en hielo. El mismo tipo de resultados se obtuvo con el pescado tratado, aunque en esta ocasión se redujeron considerablemente las pérdidas por exudación, y en muchos casos tuvo lugar un aumento de peso. La retención de fluido aumentó con la duración de la inmersión pero no con la elevación de la concentración de la misma por encima del 6 por ciento de TPF.

Sin embargo, se comprobó que las condiciones que daban una máxima retención de fluido producían un pescado con sabor inaceptable. Algunos resultados preliminares indicaron que un tratamiento muy ligero con TPF (solución al 4 por ciento durante 0.5 minutos) mejoraba la retención de humedad y la textura, lo que fue confirmado por experimentos realizados en mayor escala. En ellos se vio que tanto el pescado con pH alto como con pH bajo, había mejorado sus propiedades de retención de humedad, pero sólo el pescado con pH bajo mostraba un cambio en la textura. La adición de cloruro de sodio no determinó ninguna mejora de las condiciones.

De estos experimentos resulta evidente que el tratamiento de la carne de bacalao en condiciones adecuadas puede mejorar la retención de humedad y la calidad de los filetes.

THE loss of fluid (drip) from meat and fish products during processing is a widespread problem in the food industry, and the use of additives to counteract this is now a common practice in many countries.

Drip loss from muscle is of importance from several aspects. Firstly, it constitutes a significant economic loss to either the marketing company or the housewife, or both, depending on the processing methods. Secondly, severe fluid losses result in a drier and tougher cooked product. Finally, the nutritive value of muscle is decreased, since proteins and minerals are lost with the drip.

The most common additives to reduce drip are the sodium salts of the polyphosphates, used as mixtures of the various polyphosphates, single salts, or single salts plus sodium chloride.

Numerous investigators have reported varying results on the use of polyphosphates in fish. Dyer *et al.* (1964) found that treatment with sodium tripolyphosphate had no effect on drip loss although the net weight of the muscle was increased, while MacCallum *et al.* (1964) found that it was only effective in some instances.

Pre-slaughter injection of hexametaphosphate into lingcod was found by Buttkus and Tarr (1962) to be effective in reducing drip. Mahon (1962) and Tanikawa, Akiba and Shitamori (1963) came to similar conclusions with dipped fresh haddock and frozen cod. Tripolyphosphate was found by Hamm and Grau (1958) to be the most effective phosphate in reducing drip from meat.

Despite the volume of work reporting the use of polyphosphates in foodstuffs, there is still considerable doubt as to its effectiveness in improving the quality of fish.

In the present study two polyphosphates have been investigated, sodium tripolyphosphate (TPP) and sodium pyrophosphate (PP). From a systematic investigation into the variables which might affect the process it is shown that polyphosphate has the twofold action of decreasing fluid loss on thawing the frozen fillets and this results in an improved cooked product. In all our experiments it was found that tripolyphosphate definitely reduces the weight losses due to processing, and that it is more effective than pyrophosphate. Additions of sodium chloride did not produce any improvement over phosphate alone.

EXPERIMENTAL

The cod used in these experiments (*Gadus morhua*) were all caught in the North Sea, off Aberdeen. For the measurement of fluid loss, live fish from tanks were used, and for the taste panel assessments market fish, generally three to four days old.

Reagents

Food grade sodium tripolyphosphate (TPP) and Analar sodium pyrophosphate (PP) were used throughout. The solutions were prepared by dissolving the chemicals in cold water, with continuous agitation.

Fluid loss

By using small pieces (approximately 4 g) of muscle, only four fish were required.

The experiment was statistically designed using combinations of the following conditions:

(1) Concentration of dip: 0.084, 0.126, 0.167 molar. (This corresponds to 4, 6 and 8 per cent TPP and 2.2, 3.4, 4.5 per cent PP (w/v) respectively.)
(2) Temperature of dip: 2°C (35.6°F), 11°C (52°F), 20°C (68°F).
(3) Duration of dip: 0.5, 2, 8, 32 min.
(4) Time of dipping after death: 0, 2, 4, 6 days.

The fish were killed by a blow on the head, filleted and sectioned, packed in polythene bags and stored for various periods in crushed fresh water ice. The samples were then processed as either the undipped controls or under various conditions in the polyphosphate solutions. They were frozen for 24 h at −29°C (−20°F), and then thawed at 11°C (52°F) under paraffin (kerosene) for 24 h. This technique allows the ready separation of fluid from small samples and prevents any loss due to evaporation. Weighing the sample before dipping and freezing and after thawing gives the net weight change. This is frequently a more useful parameter than a measurement of the fluid lost, which includes the fluid absorbed during dipping.

The results are expressed as the final muscle weight relative to an original starting weight of 1 g of sample.

Taste panel assessment

The market fish were filleted, and one fillet polyphosphate treated and the other kept as the undipped control. They were frozen for 24 h at −29°C (−20°F), and portions cooked by steaming over a water-bath for 1 h. These were then assessed by a taste panel for hardness (softness), wetness (dryness) and flavour. The hardness of the muscle was also measured objectively with a texturometer, the instrument picking up changes more readily than the panel, particularly in soft samples.

The results are reported on separate continuous scales from 0 to 4 for the two texture parameters. A score of 2.0 is a perfect sample, with 2 to 4 representing hard or dry, and 0 to 2 soft or wet textures.

RESULTS AND DISCUSSION

Fluid retention

Fig 1 shows the effect of various storage periods in ice on the final weight of the untreated muscle after freezing and thawing. This is the mean curve for four fish used as the untreated controls. It can be seen that processing the *pre-rigor* fish has a considerable effect on the water-retention properties of the muscle. This is due to the severe shrinkage which can occur during *rigor* in excised muscle. With fish kept from two to six days on ice before freezing the final weight rises gradually which indicates the longer the fish is kept on ice before freezing the less liquor loss will occur on thawing.

The weight changes brought about by phosphate dipping the fish are shown in fig 2 for TPP and fig 3 for PP. The mean of the controls for each experiment are also shown for comparison. The final weight of the sample was found to be independent of the temperature of the dipping solution in the range 2° to 20°C (35.6° to 68°F), and the results of the three temperatures studied have therefore been averaged to give each point in the figures.

A number of interesting trends are apparent. As might be expected the final weight increased with time of dipping, although this is not a linear relationship. The overall shape of the curves is similar to the controls, the *pre-rigor* reactions still influencing the dipped fish. The 0.5 and 2 min curves show the big increase between none and two days after death treatment, with comparatively small changes after this. However, the differences between the none and two days become less with increased dipping times or strength of the solution, and a minimum in the curves at four days becomes more apparent. This is particularly well shown with PP in fig 3. It would appear that the minimum is caused by an additional reaction of the pyrophosphate in the muscle, and at the lowest PP concentration the weight change in the dipped samples

when treated four days after death, is almost the same as the control. The loss of PP activity with these fish presumably coincides with the formation of an unstable compound which either complexes the PP, or decomposes it. In the latter case this could be the release of a pyrophosphatase from the cell. In contrast, the activity of the TPP is barely effected in the four-day-old fish.

In both TPP and PP solutions the highest concentrations tend to produce the greatest increases, but the differences between the 0.126 and 0.167 molar are not very distinct. On an equi-molar basis TPP is more effective than PP in keeping the muscle weight constant through processing, and can produce weight gains if required. (This may not be beneficial from texture/quality aspects.) In all instances both TPP and PP treatments definitely reduced weight losses due to processing.

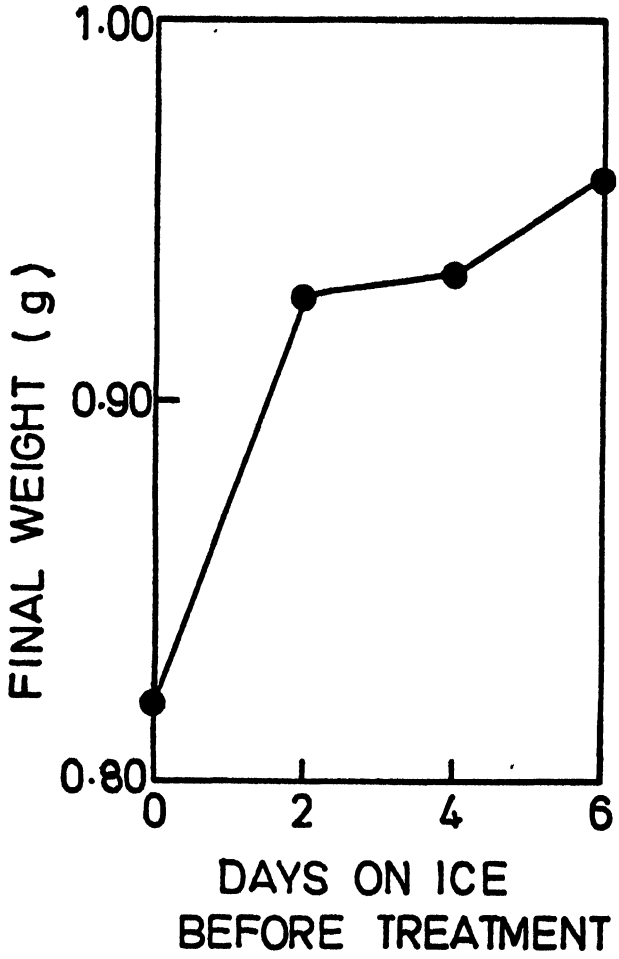


Fig 1. Final weight of undipped controls after freezing and thawing

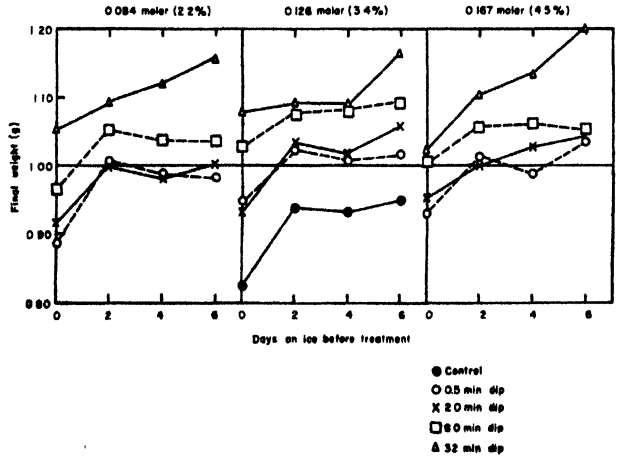


Fig 2. Effect of TPP on final weight of muscle after processing

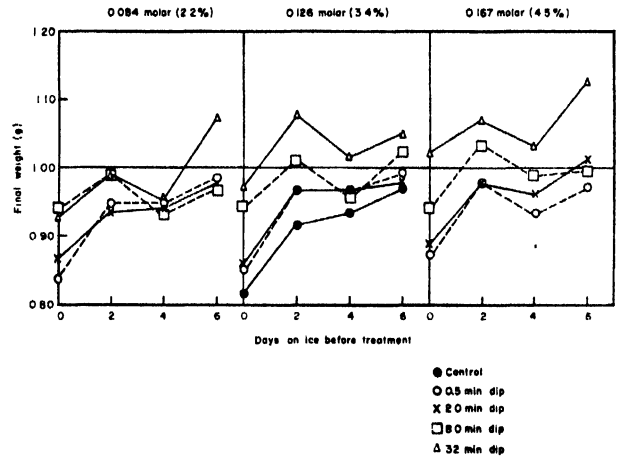


Fig 3. Effect of PP on final weight of muscle after processing

Cooked texture

Duration of dip in TPP. The ideal pre-treatment should produce the desired improvements to the final product with a minimum uptake of additive and short processing times. From the previous experiments 0.084 molar TPP for either 0.5, 2 or 8 min with fish more than two days old would appear suitable. Whole fillets were dipped for the varying times, frozen, cooked and taste panelled. The results are shown in table 1.

TABLE 1. FILLETS DIPPED FOR 0.5, 2 AND 8 MIN IN TPP

Duration of dip	*Wet–dry*	*Soft–hard*		*Flavour*	*Number of fish*
		Panel	*Texturo-meter*		
Control	2.8	2.9	2.9	Good	7
0.5 min	2.9	2.5	2.4	Good	7
2 min	2.9	2.6	2.5	Good	3
8 min	3.1	2.7	2.4	Slightly salty	3

<2 wet/soft 2.0 perfect fish >2 tough/dry

The controls here had a slightly firm, dryish texture, but were acceptable fish. The dipped samples showed some very interesting results. It appears that the dryness of the muscle is not improved by phosphates and, if anything, becomes worse at the longer dipping times. This would indicate that either the water taken up in the raw muscle is readily removed on cooking, or it is in some "bound" state and not detectable in organoleptic assessments. The muscle is softened by treatment, but this is apparently not dependent on the time of dipping.

It would appear from these results that a very light treatment, i.e. 0.5 min dip in 0.084 molar TPP, produces significant improvements in water retention and textural properties.

pH of fish. The serious problems of texture and fluid loss are caused by low pH fish. To determine the effect of muscle pH on the polyphosphate reaction a number of fish were divided into two groups, those of pH <6.3 and >6.3. These were dipped in 4 per cent TPP for 0.5 min, and the results are shown in table 2.

TABLE 2. EFFECT OF MUSCLE PH ON TPP-TREATED SAMPLES

pH	*Wet–dry*		*Soft–hard*			
			Panel		*Texturometer*	
	C	D	C	D	C	D
<6.3	3.1	2.8	2.5	2.1	2.1	1.5
>6.3	2.8	2.8	2.1	2.0	1.5	0.9

C = control D = dipped

These results show that both the dryness and hardness of the low pH group were improved by dipping, but the panel could not distinguish any significant change in the high pH fish. However, the texturometer showed that both samples had been softened to the same extent. This is an indication of the panel's inability to grade soft fish. The final weights of these fish compared with 1.00 g starting weight are given in table 3.

TABLE 3. WEIGHT CHANGES IN HIGH AND LOW PH FISH DUE TO PROCESSING RELATIVE TO 1 G STARTING WEIGHT

pH	*Control*	*Dipped*
<6.3	0.981	1.001
>6.3	0.988	1.009

The fish were all fairly fresh, and the drip losses from the controls are quite small. The low pH group lost slightly more, however, but both groups increased by the same amount due to dipping, leaving the difference between them the same.

From these results it may be concluded that low and high pH fish are affected to approximately the same extent by TPP. With high pH fish this may turn an acceptable fish into one which is really too soft, but apparently this change cannot be picked up by a panel. It appears, therefore, that marked improvements are obtained only with low pH fish, but that high pH fish will not suffer unduly from treatment.

PP and texture. Although the PP was less satisfactory than TPP for improving water retention, it was considered possible that PP might have a greater effect on the texture. For this experiment 0.167 molar PP was compared with the 0.084 molar TPP. The results are shown in table 4.

TABLE 4. COMPARISON BETWEEN 0.084 MOLAR TPP AND 0.167 MOLAR PP ON TEXTURAL PROPERTIES

Treatment	*Wet–dry*	*Soft–hard*		*Number of fish*
		Panel	*Texturometer*	
Control	2.8	2.8	2.7	4
0.084 molar TPP	2.8	2.6	2.3	4
Control	2.6	2.8	3.2	4
0.167 molar PP	2.8	2.8	3.1	4

It can be seen that the PP does not produce any improvement to the texture, despite its doubled concentration over TPP. From the weight changes shown in fig 3 the 0.167 molar PP for 0.5 min dipping time has a negligible effect on the water content. This indicates that improvements in texture will not occur unless the water content is increased, i.e. there is not a purely ionic effect of modifying the muscle or water structure and so changing texture.

Polyphosphates and sodium chloride. Sodium chloride is a commonly-used additive to phosphate solutions, where it is reported to enhance the action of the phosphates. Two and 4 per cent (w/v) solutions of NaCl with 0.084 molar TPP and 0.167 molar PP were investigated, and the results are shown in tables 5 and 6.

With both TPP and PP the addition of 2 per cent NaCl had a negligible effect on the texture. The 4 per cent solutions showed no improvements over TPP alone, and the samples were downgraded for flavour.

TABLE 5. 0.084 MOLAR TPP FOR 0.5 MIN DIP WITH THE ADDITION OF NaCl

Concentration of NaCl	*Wet–dry*	*Soft–hard*		*Number of fish*
		Panel	*Texturometer*	
Control	2.8	2.7	2.5	6
2%	2.7	2.7	2.6	6
Control	2.8	2.5	2.4	6
4%*	2.6	2.4	2.1	6

* Salty flavour.

TABLE 6. 0.167 MOLAR PP FOR 0.5 MIN DIP WITH THE ADDITION OF NaCl

Concentration of NaCl	*Wet–dry*	*Soft–hard*		*Number of fish*
		Panel	*Texturometer*	
Control	2.7	3.1	3.3	4
2%	2.9	2.9	3.1	4
Control	2.6	2.9	3.0	4
4%*	2.5	2.6	2.5	4

* Salty flavour.

CONCLUSIONS

From our experiments it is clear the tripolyphosphate treatment of cod fillets does reduce the weight losses which can occur through freezing and thawing processes. Only a light treatment in the TPP, i.e. 0.5 min dip in a 0.084 molar (4 per cent) solution was required to produce improvements in both the water retention and texture properties of the muscle. Best results are obtained in *post-rigor* muscle.

Pyrophosphate in all our experiments was less efficient than TPP, and also suffered a further reduction in its effectiveness in fish which had been stored four days on ice. Additions of NaCl to either solutions did not produce any additional improvements to the process.

ADDENDUM

Bacterial contamination of fillets due to polyphosphate dipping

A. H. Sutton and **J. I. W. Anderson** supply this further information:

The dipping procedures already used in the fishing industry are known potential sources of bacterial contamination, and the polyphosphate dips are no exception to this.

There are two problems to be considered. Firstly, the effect of bacterial contamination on the keeping properties of the fillets. This will presumably get worse with the age of the solution, which raises the second problem. What is the useful working life of the dips?

An unacceptable dip can be caused either directly by high bacterial counts or indirectly by bacterial hydrolysis of the polyphosphates to ineffective orthophosphate.

We have to date only carried out a limited investigation into the magnitude of this problem, but the results are sufficiently encouraging that further trials will be at the factory pilot plant level. The experiment was designed to show if fresh cod fillets suffered a decrease in quality when stored up to 11 days on ice after dipping in well used, bacterially-contaminated tripolyphosphate solution.

Experimental

An 8 per cent by weight solution of sodium tripolyphosphate was used for this experiment. When freshly prepared this had a negligible bacterial count. A sufficient quantity of fish was dipped to produce considerable visible contamination, when discarding or filtering plus replenishment would be necessary. One fillet of a cod kept for 48 h on ice was then dipped and stored in a polythene bag (on ice). The other fillet served as an undipped control. The solution was kept for 24 h at 10°C (50°F) and a second fish dipped.

For the bacteria counts 5 g samples of the fillets were macerated in a suitable growth media and cultured on 0.1 per cent yeast extract/peptone, sea-water agar plates. Muscle samples were taken before and after dipping and at suitable time intervals up to 11 days. The solution was counted after dipping the cod on the first and second days.

After a total of 13 days on ice for one fish and 12 days for the other, the experiment was concluded and the remaining portions of fillets cooked and taste panelled.

Results and discussion

The bacterial counts on the solution and the muscle are shown in fig 1.

It can be seen that apart from the values immediately after dipping, the bacterial growth rate in the dipped and control samples is very similar. With both fish the dipped fillets had a count of about 10 times higher than the controls, but this did not effect the flavour or quality of the fish. It appears that the dip can be used for at least two days when kept at fairly low ambient temperatures, but with high throughputs this will generally not be necessary.

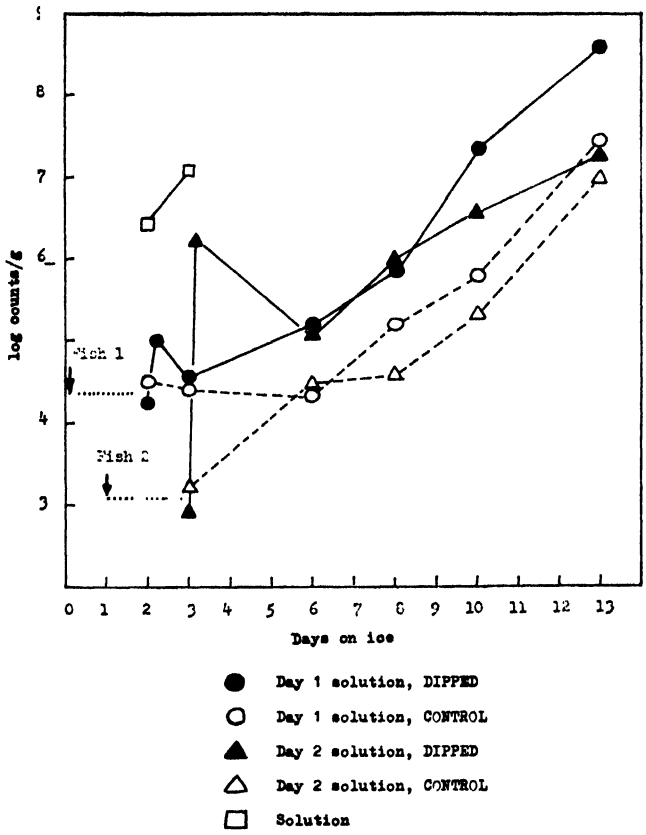


Fig 1. Bacterial counts on the solution and the fish muscle

These results indicate that phosphate dipping is not likely to introduce any serious bacteriological problems into the factory.

References

BUTTKUS, H and TARR, H L A 1962 *Fd Technol., Champaign*, **16**, 84.

DYER, W J, BROCKERHOFF, H, HOYLE, R J and FRASER, D I 1964 *J. Fish. Res. Bd Can.*, **21**, 101.

HAMM, R and GRAU, R 1958 *Z. Lebensmittelunters. u. -Forsch.*, **7**, 196.

MACCALLUM, W A, SHIOH, H S, CHALKER, D A, DYER, W J 1964 and IDLER, D R *J. Fish. Res. Bd Can.*, **21**, 539.

MAHON, J H 1962 U.S. Patent No. 664851, 29th May.

TANIKAWA, E, AKIBA, M and SHITAMORI, A 1963 *Fd Technol., Champaign*, **17**, 87.

DISCUSSION

Little (U.K.): I think both speakers are agreed that dipping in a polyphosphate increases yield. Dyer says that it also decreases drip yield whereas Sutton is not so sure. Dyer was also less convinced about the improvement in eating quality by dipping, though this would seem to be a debatable point.

He did say there have been some results which tend to say there is and some tend to say there isn't. But I think both speakers are agreed that it is a very valuable process.

Love (U.K.): I agree with Dyer that polyphosphates do not seem to improve either the texture or the extractable protein of the fish. The effect really seems to be a superficial one. If you dip fillets in the polyphosphate-brine solution recommended by Mahon, drain them, freeze in the normal commercial way and then thaw them, photomicrographs of the treated surface show a thin continuous film of protein, which seals off the majority of extra-cellular channels that communicate with the cut surface and presumably stops exudation. The dip seems to dissolve some of the surface protein, which then concentrates and adheres to the cut surface both during draining and also in the period before the fillets are actually frozen. If the protein is very denatured, then it will presumably not dissolve or form a skin, and this fits in with an observation made, I think, by Dyer's group, that if the fillets are thawed out before much denaturation has occurred, and then dipped, the drip is effectively reduced, but if there has been denaturation from long storage at too high a temperature, then no improvement results.

The fact that the old-fashioned brine dips caused the fat to become rancid during storage is an important one. Strong brine was used, and some sodium chloride almost certainly entered the flesh. The eutectic temperature of sodium chloride is at about −22°C (−8°F), so it is probable that on subsequently storing at, say, −20°C (−4°F), a significantly larger proportion of cell fluids near the surface remained unfrozen, allowing atmospheric oxygen to dissolve, diffuse and react with the tissue fats. Now, the interesting thing about 12 per cent sodium tripolyphosphate solution is that its freezing point is only two or three degrees below that of water, so that, at all commercial freezing temperatures, its presence should not affect the proportion of unfrozen tissue water at all—that is, apart from temperatures in the "superchilling" range, around −2°C (28.4°F). This fits in with the literature reports that fat oxidation is not accelerated in frozen fish previously dipped in polyphosphate solution.

Aagaard (Denmark): I wish to comment on the following papers: "Polyphosphate treatment of cod muscle", by A. H. Sutton, "Effect of brining and polyphosphate on yield and quality", by W. J. Dyer, and "Conditions of Newfoundland offshore fish and its influence on quality after single and double freezing", by MacCallum *et al.* My comments are based on experiments on the effects of double-freezing and polyphosphate treatment of cod carried out at the Technological Laboratory of the Danish Ministry of Fisheries. These experiments were not finished until a few months ago so it has not yet been possible to prepare a paper on our findings.

Our experiments have been concentrated on quality problems arising from doubl-freeezing of cod and on possible ways of diminishing unwanted quality deterioration. Experiments have been carried out with Newfoundland cod, frozen at sea *pre-rigor*, and with cod caught in Danish waters, killed by cutting the throat, gutted, iced and finally frozen *post-rigor*. The two types of fish were caught in April and March 1966 respectively. Quality investigations have been carried out by taste panel assessment, using scores on a scale from 0 (bad) to 10 (good). Preparatory to taste panel assessment the fillets were normally cooked in 2 per cent salt water at 80°C (176°F) for 15 min.

For both types of raw material, a decrease was found in both flavour and texture, when double-frozen fillets were compared with single-frozen fillets. The decrease in flavour was about 0.6 points in both cases. The decrease in texture was only 0.4 to 0.5 points for the *pre-rigor* frozen Newfoundland cod as compared with a significant decrease of about 1 point for the inshore caught, *post-rigor* frozen Danish cod.

Different ways of diminishing the quality loss caused by thawing and refreezing have been investigated. Among these are alterations in the method of processing and consequently changes in the household preparation method. After thawing, the frozen raw material (i.e. the frozen, gutted whole cod) was manufactured into two different products. The first was boneless fillets, which were refrozen, cold stored, thawed and prepared by cooking in salt water; the second, boneless fillets, which were refrozen as blocks, cut into fish sticks, battered, breaded, deep-fat fried, refrozen again, cold stored and prepared by frying in a pan from the frozen state.

These two products were assessed by the taste panel over a long period. The quality level of the fish sticks was found to be about 0.6 point higher in both flavour and texture than that of the cooked fillets. It therefore seems possible to mask flavour and texture deteriorations to a certain extent by changing the methods of processing and kitchen preparation, for instance, by frying instead of cooking or simmering.

Polyphosphate treatment is another possible method of reducing quality deterioration caused by double freezing. With regard to flavour, polyphosphate treatment was found to have limited effect at the beginning of the cold storage period, improving taste scores by about 0.3 to 0.5 points. With prolonged cold storage periods the flavour difference between treated and untreated fillets disappeared. Texture, however, was markedly improved (about 1 point) by the polyphosphate treatment, as it reduced both toughness and dryness. This was the case with both single- and double-frozen fillets. The improvement of the texture of double-frozen fillets was so marked that the difference in texture between single-frozen, untreated fillets and double-frozen treated fillets was considerably reduced.

The polyphosphate treatment was a 2-min dip in a 12½ per cent sodium tripolyphosphate solution. The ratio between weight of fillets and dip solution was 14 to 1. By this dipping the phosphorous content was increased by 0.1 per cent and the free thaw-drip was reduced by about 5 per cent. The mean value of the thaw-drip was 8 per cent for untreated fillets and 3 per cent for polyphosphate-treated fillets. For single-frozen fillets, the free thaw-drip was less than the amount of liquid absorbed by the dipping process prior to freezing. For double-frozen fillets the two amounts were equal.

MacCallum (Canada): It is generally recognized that tripolyphosphate (TPP) treatment has some advantages, namely:

(1) Use of TPP helps the producer avoid sustaining significant financial loss. If the pack is treated with polyphosphate there is no appreciable weight loss to be detected by weighing the pre-packed fillets and later weighing the frozen blocks. On the other hand, there can be considerable difference between the weight of pre-packed untreated fillets and the weight of the frozen block. In packing untreated fillets for freezing, the producer runs considerable risk of selling underweight blocks or may have to overpack by a considerable margin.

(2) The producer, who uses polyphosphates in just sufficient quantities to prevent accumulation of fish juices in the pans before freezing, is assured of marketing a block without pockets of ice and with uniform corners, With these blocks, there is every likelihood that subsequent processing into cooked portions can be done to the entire satisfaction of the cooking plant.

(3) We have concluded from our work with both trap-caught inshore cod and Grand Bank cod, that TPP treatment prior to freezing results in less pronounced toughening during cold storage at −23°C (−10°F). Whether the improvement effected has practical value is not known. To answer this

question we would have to know if there is an increased desire, on the part of the public at the present time, for cod, over that existing before any of our production was polyphosphate-treated.

There are some problems and limitations in the commercial application of TPP. We have records showing the difficulty encountered in the laboratory and in industry (where batch treatments are carried out) in obtaining uniform uptake in TPP. This variable uptake can have at least two bad effects; first, those "treated" fillets which have not absorbed a sufficient quantity of dip solution can lose significant quantities of fish fluids before freezing; and second, there can be a costly waste of the TPP in fillets which are overtreated. We do not have data on the uniformity of uptake of TPP, using the conveyorized equipment which is now available.

There is some question concerning customer reaction to the appearance of single fillets, or portions of fillets, treated with TPP before freezing. Experience in supplying restaurants with fish fillets, has demonstrated the need to use less TPP on some species of fish than on others. The amount of solution absorbed can affect the appearance and "feel" of the fish before cooking and also the length of time required for frying, in order to produce a cooked portion of desired consistency. Therefore, the problem of the primary processor is to add only sufficient TPP solution to the fillet to keep free drip within the bounds required in the production of frozen, ice-free fillets and blocks.

Also, in primary production, the high cost of treatment in relation to the selling price of the fish can be another limiting factor. This cost can range up to ½ c/lb of fillet treated, depending on the species.

The practice of tumbling batch lots of fillets in TPP solution is limited too, since this operation may be too severe for soft-textured or "flaky" fillets. It might be, that conveying through a TPP solution, or basket dipping, using hand labour or motorized equipment, would be essential for treating the fillets of most thawed fish, whether these are to be refrozen or distributed unfrozen.

Freezing of Tropical Fish

by A. N. Bose

(with addendum—Refrigerated sea water in the preservation of tropical fish)

Freezing of tropical fish

The paper reviews the work carried out in India on the technological problems involved in the freezing of certain varieties of tropical fish and shellfish of commercial importance. The *post-mortem* biochemical changes in the tissue of the fish have been studied and their influence on the quality of the frozen fish has been reported. Among the normal glycolytic metabolites found in the tissue, unusually high level of free ribose could be detected in tropical fish even in *rigor* state. Rapid nucleotide dephosphorylation was observed during pre-process ice storage. Considerable loss of amino acids was observed in prawns stored in ice for four days. During prolonged storage of certain varieties of fish like individually quick-frozen (IQF) sardines a slow but steady increase of α-amino nitrogen has been noted. The bacterial flora on the skin of sardines were found to be predominently *Achromobacter* and *Vibrio* while in the gut the luminous bacteria were more prominent. With fresh marine prawns *Vibrio* were predominating in the flora while *Aeromonas* were more important with the backwater prawn. Bacterial counts in frozen fish stored at −23.3°C (−10°F) steadily decreased while those stored at −12.2°C (10°F) increased after an initial fall. The bacterial flora on frozen fish prepared from raw fish kept up to two days in ice decreased continuously in storage. However, the count of those fresh fish kept more than two days in ice, increased after an initial fall.

Initial temperature of the raw fish was observed to have a significant influence on the time required for the material to pass from 0° to −5°C (32° to 23°F) during freezing. The freezing rates with different methods of commercial freezing were studied.

Pre-dip treatment with sodium hexametaphosphate and sodium polyphosphate improved the organoleptic quality particularly colour and flavour of the frozen prawns and reduced the thawed drip loss. The glaze solution containing 0.5 per cent sugar and 0.5 per cent of salt gave an improved product with headless and peeled-deveined prawn. Extensive data have been collected on the shelf-life of the frozen fish produced and packed under different conditions in India. The changes occurring in the frozen fish during prolonged storage have been studied with particular reference to protein denaturation and lipid oxidation. The temperature fluctuations which frozen fish might undergo during commercial transport conditions have been studied and their influence on the quality of the product has been evaluated.

Congélation des poissons tropicaux

La communication passe en revue les travaux effectués en Inde sur les problèmes technologiques que pose la congélation de certaines variétés de poissons tropicaux et de mollusques ou de crustacés présentant une importance commerciale. Les études ont porté sur les modifications biochimiques *post mortem* dans les tissus des animaux et sur leur influence sur la qualité du produit congelé. Parmi les métabolites glycolytiques normales des tissus, des niveaux exceptionnellement élevés de ribose libre ont pu être détectés dans le poisson tropical même à l'état de *rigor mortis*. Une rapide déphosphorylation des nucléotides a été observée durant l'entreposage sous glace précédant le traitement. Dans des crevettes stockées sous glace durant quatre jours, on a observé une perte considérable d'aminoacides. Un accroissement lent mais régulier d'azote alpha-aminé a été relevé durant l'emmagasinage prolongé de certains poissons du type sardine surgelés individuellement. La flore bactérienne de la peau des sardines était composée en majorité d'*Achromobacter* et de *Vibrio*, tandis que les bactéries luminescentes se trouvaient en plus grand nombre dans le tube digestif. Chez les crevettes marines fraîches, la flore comptait surtout des *Vibrio*, tandis que les *Aeromonas* prédominaient chez les crevettes provenant d'eaux intérieures. Dans le poisson surgelé, stocké à −23,3°C (−10°F), le nombre de bactéries a décru régulièrement, tandis que dans le cas d'entreposage à −12,2°C (10°F), il a augmenté après avoir d'abord baissé. Dans le cas du poisson congelé préparé à partir de poisson frais conservé sous glace jusqu'à deux jours, la flore bactérienne a diminué progressivement durant l'entreposage. Cependant, lorsque le poisson frais était resté sous glace plus de deux jours, le nombre de bactéries a augmenté après une chute initiale.

On a relevé que la température initiale du poisson frais exerçait une influence marquée sur le temps requis par la matière première pour passer de 0° à −5°C (32° à 23°F) durant la congélation. L'étude a porté sur les taux de congélation observés avec différentes méthodes de congélation commerciales.

Le traitement préalable à l'héxamétaphosphate de sodium et au polyphosphate de sodium a amélioré les qualités organoleptiques, notamment la couleur et la saveur, des crevettes congelées, et réduit l'exsudat à la décongélation. La solution employée pour le givrage, qui renfermait 0,5 pour 100 de sucre et 0,5 pour 100 de sel, a fourni un produit amélioré à partir de crevettes étêtées, décortiquées et éviscérées. De nombreuses données ont été rassemblées sur la durée de conservation des poissons congelés produits et emballés dans diverses conditions en Inde. Les modifications qui interviennent dans le poisson congelé durant un entreposage prolongé ont été examinées notamment du point de vue de la dénaturation des protéines et de l'oxydation des lipides. On a également étudié les variations de température que peut subir le poisson congelé durant le transport commercial, et évalué leur influence sur la qualité du produit.

Congelación del pescado tropical

El trabajo expone la labor realizada en la India sobre los problemas tecnológicos de la congelación de ciertas variedades de pescado y mariscos tropicales de importancia comercial. Estudia los cambios bioquímicos *pos-mortem* del tejido del pescado, explicándose su influencia sobre la calidad del pescado congelado. Entre los metabolitos glicolíticos normales del tejido, se ha detectado en el pescado tropical una cantidad insólitamente elevada de ribosa libre, incluso en el estado de "*rigor*". Durante la conservación en hielo previa a la elaboración se observó una rápida desfosforización de los nucleótidos. En los camarones conservados en hielo durante cuatro días se observó una considerable pérdida de aminoácidos. Durante el almacenamiento prolongado de ciertas variedades de pescados análogos a la sardina (congelación rápida individual) se ha notado un aumento lento, pero constante, del nitrógeno α-aminado. La flora bacteriana encontrada en la piel de las sardinas era predominantemente *Achromobacter* y *Vibrio*, mientras que en las vísceras eran más abundantes las bacterias luminosas. La flora predominante en los langostinos marinos era *Vibrio*, mientras que en los camarones de aguas salobres eran más importantes las *Aeromonas*. El recuento bacteriano del pescado congelado y conservado a −23,3°C (−10°F) disminuía regularmente, mientras que el del almacenado a −12,2°C (10°F) aumentaba, después de un descenso inicial. La flora bacteriana del pescado congelado después de dos días de conservarlo en hielo disminuía continuamente durante el almacenamiento. El recuento del pescado fresco mantenido en hielo más de dos días, en cambio, aumentaba después de un descenso inicial.

Se observó que la temperatura inicial del pescado tenía una significativa influencia para que, durante la congelación, se enfriase de 0° a −5°C (32° a 23°F). Se estudiaron las velocidades de congelación con diferentes métodos de congelación comercial.

La inmersión previa en hexametafosfato sódico y polifosfato sódico mejoraba la calidad organoléptica, particularmente el color y el sabor de los langostinos congelados y reducía las pérdidas debidas al exudado por descongelamiento. La solución para glasear con un 0,5 por ciento de azúcar y un 0,5 por ciento de sal, empleada con los camarones descabezados, eviscerados y sin caparazón, mejoró el producto. Se han obtenido muchos datos sobre la duración en almacén del pescado congelado preparado y envasado en diferentes condiciones en la India. Se han estudiado los cambios ocurridos en el pescado congelado durante un almacenamiento prolongado, con particular referencia a la desnaturalización de las proteínas y a la oxidación de los lípidos. Se han estudiado las fluctuaciones de temperatura que el pescado congelado podría experimentar durante su transporte comercial, y su influencia sobre la calidad del producto.

THE fish-freezing industry in India is of rather recent origin. From a very modest beginning with less than a ton in 1951, the industry now produces over 10,000 t of frozen shellfish and fish annually. Today a good percentage of all the commercial species of prawns (*Penaeus indicus, Metapenaeus dobsoni, M. affinis* and *P. stylifera*) caught in India is processed in the freezing plants. Quick freezing of lobster (*Panulirus burgeri*) tails is also carried out on a limited scale.

Sardines (*Sardinella longiceps*), the most important of the teleosts available in abundance during seasons have so far not been utilized for commercial-scale freezing. Other commercially important varieties of fish such as tuna (*Makaira nigricans* and *M. indica*), pomfret (*Stromateus* spp.) and mackerel (*Rastrelliger kanagurta*) are frozen in some of the freezing plants in the country for sale in the lean seasons as fresh-fish after thawing.

Rapid progress in the frozen-fish industry brought out several technological problems. These required studies on factors which influence the quality of the finished frozen-fish industry such as chemical and bacteriological quality of raw fish, the changes occurring during pre-processing storage and during processing, the type of pack, the method of freezing and the temperature fluctuations during storage and transport.

QUALITY OF RAW MATERIAL

Chemical

Studies carried out at this Institute showed that raw prawns were more susceptible to rapid deterioration than teleosts and that they would retain prime quality only for about 4 h at atmospheric temperatures (25° to 30°C, 77° to 86°F).

Post-mortem biochemical changes occurring in Indian prawns were reported by Velankar *et al.* (1961a, 1961b) and Rajendranathan Nair and Bose (1965). It was shown from a study of the distribution of the glycolytic metabolites that fresh prawns handled commercially are in *post-rigor* condition. Estimations of the changes in free sugars, sugar phosphates and nucleotides indicated the course of glycolytic cleavage occurring during the storage of prawns. The levels of free sugars: glucose and ribose, and sugar phosphates: glucose-1-phosphate, glucose-6-phosphate, fructose 1 : 6-diphosphate and ribose-5-phosphate, underwent significant changes during storage in ice (table 1). As compared with oil sardine which could be obtained in *pre-rigor* condition, these sugar compounds showed fluctuating levels in prawns. Unusually high levels of ribose could be detected in fish even in *rigor* state.

No significant change has been noted in the levels of sugars and sugar phosphates immediately after freezing and during storage for two weeks at −23.3°C (−10°F) (table 2).

Nucleotide dephosphorylation occurring in fish during ice storage and in samples in frozen storage after subsequent freezing was studied in prawns and sardines. Rather rapid dephosphorylation took place in the fish during ice storage (table 3).

Tomlinson, Geiger and Roberts (1962) observed changes in some of the labile constituents in frozen albacore tuna related to storage conditions prior to freezing. Working on Indian fish like mackerel, pomfret and sardines, Pawar and Magar (1966) had shown that R value (ratio of barium acetate non-precipitable ribose to total acid soluble ribose) was higher for slow-frozen fish than for quick-frozen fish. Studies on storage of frozen sardines at −23.3°C (−10°F) and −12.2°C (10°F) indicated that dephosphorylation continued to occur at the same rate at the two temperatures. Tomlinson, Jonas and Geiger (1963) were of the opinion that degradation of acid soluble phosphorus compounds would continue down to −20°C (−4°F) and not at −30°C (−22°F).

It was reported by Govindan (1962), Rajendranathan Nair and Bose (*loc. cit.*) and Susamma *et al.* (1962) that during storage of Indian prawns in ice, water-soluble protein and other nitrogenous extractives especially amino acids were leached out by melting ice and when such material was used for freezing, the quality of the raw material was reflected in the final product. Depending upon the type of pack such as round, headless and peeled-deveined, the extent of loss of these compounds was also variable. The study of the quantitative dis-

TABLE 1. CHANGES IN FREE SUGARS AND SUGAR PHOSPHATES IN PRAWN (*M. dobsoni*) DURING ICE STORAGE

Days in ice	*Glucose*	*Glucose 1-phosphate*	*Glucose 6-phosphate*	*Fructose 1 : 6-diphosphate*	*Ribose 5-phosphate*	*Ribose*
			μM/100 *g*			
0	183	3.2	25.5	8.6	1.8	15 0
3	146	2.7	43.7	7.6	6.2	18.7
5	137	3.2	14.8	6.9	7.3	24.1
7	130	2.8	16.1		3.4	31.7
11	71.5	2.7	14.7	5.9	1.6	14.8

TABLE 2. CHANGES IN FREE SUGARS AND SUGAR PHOSPHATES IN OIL SARDINE (*Sardinella longiceps*) DURING FREEZING

Sample	*Glucose*	*G-1P*	*G-6P*	*F-6P*	*F-1 : 6DP*	*R-5P*	*Ribose*
				μM/100 *g*			
Fresh	280	4.9	9.8	15.7	6.9	8.9	34.0
Fresh frozen	269	5.1	11.6	10.8	5.0	10.4	42.0
Iced—four days	249	3.1	31.4	12.4	5.7	12.1	52.0
Iced—four days and frozen	215	4.2	33.6		4.2	16.4	61.3

TABLE 3. CHANGES IN NUCLEOTIDE CONCENTRATIONS IN FISH HELD IN ICE AND FROZEN

Sample	Days in ice	Total nucleotide concentration ($\mu M/g$)		R. value*		
		Ice storage	Frozen storage at −23.3°C (2 months)	Ice storage	Frozen storage at −23.3°C (2 weeks)	Frozen storage at −23.3°C (2 months)
IQF sardine (*S. longiceps*)	0	11.6	9.3			51.2
	1	12.6	—			—
	2	13.1	—			54.1
	3	7.9	—			59.2
	4	6.9	5.7			62.7
Prawn (*P. indicus*) headless	0			25.1	29.9	
	2			44.6	44.3	
	3			46.4	45.3	
	5			45.9	57.2	

* R. value—Ratio of barium acetate non-precipitable ribose to total acid soluble ribose (Mejbaum, 1939).

TABLE 4. CHANGES IN FREE AMINO ACIDS DURING ICE STORAGE AND FROZEN STORAGE OF PRAWNS (*P. indicus*) IN MG/100G MUSCLE

Amino acid	Ice storage					Frozen				
	Fresh	1 day	2 days	3 days	4 days	Fresh	1 day iced	2 days iced	3 days iced	4 days iced
Cystine	0.56	0.56	0.32	0.36	0.32	0.56	0.44	0.36	0.32	0.32
Proline	46.8	38.24	28.73	19.67	11.58	42.4	34.61	22.43	16.68	4.43
Tryptophan	6.88	6.37	5.24	5.13	5.18	6.27	5.28	4.18	3.78	3.26
Phenyl alanine	13.62	5.31	3.56	2.71	1.89	10.71	2.71	1.67	1.48	1.34
Serine	25.11	14.37	7.21	4.31	3.18	21.38	11.37	3.58	2.89	1.79
Lysine	12.88	7.79	5.13	5.50	5.0	10.73	5.82	4.37	3.71	3.19
Valine	8.37	5.39	4.12	3.83	2.16	6.98	4.11	3.08	2.33	2.09
Leucine	12.44	7.8	4.88	3.19	3.22	10.73	5.32	3.63	2.79	2.48
Glycine	194.7	116.3	96.27	52.73	48.39	181.7	104.3	84.76	47.64	37.58
Tyrosine	15.37	7.73	3.75	3.17	3.09	11.39	4.18	2.87	2.19	2.42
Methionine	28.76	18.96	12.84	7.33	5.84	22.67	15.18	9.73	5.38	4.47
Histidine	12.28	9.57	7.89	6.55	6.31	11.71	7.36	5.76	4.37	4.13
Threonine	7.38	5.36	4.72	3.47	2.62	5.89	3.49	2.98	2.14	1.93
Isoleucine	23.0	17.63	15.37	12.58	10.74	19.57	14.0	13.81	11.32	9.84
Arginine	29.81	25.14	27.80	17.72	15.82	24.75	22.72	17.38	14.61	11.33
Glutamic acid	36.73	31.51	26.32	21.84	18.38	34.89	29.94	24.32	19.52	17.32

tribution of essential amino acids in prawns both fresh and ice stored for four days showed that the loss is considerable. Although freezing did not appreciably affect the quantities of the amino acids (table 4), the duration of ice storage was a factor in determining the amino acid contents of the frozen material.

During prolonged storage of certain varieties of fish, for example individually quick-frozen (IQF) sardines a slow but steady increase of α-amino nitrogen was observed. Belly tissues of sardine had enzymes with strong proteolytic action (activity = 160 mμM tyrosine/h/mg protein). The increase in α-amino N might be due to the action of such enzymes. Silbert and Schmidt (1961) observed that the enzymes were active even at −17°C (1.4°F).

Bacteriological

Sardines landed near Cochin area showed a bacterial plate count in the skin and flesh in the range of 4.4×10^3 and 1.1×10^7/g depending upon season and extent of handling. The counts in the gut were always higher ranging from 6.0×10^4 to 8.4×10^8/g, with a preponderance of luminous bacteria of the type described by Liston (1957). The composition of the bacterial flora was on the average *Pseudomonas* 9.6 per cent, Achromobacter 22.6 per cent, *Vibrio* 29.6 per cent, *Flavo-bacterium* 5.2 per cent, *Corynebacterium* 7.2 per cent, *Micrococcus* 6.4 per cent, *Bacillus* 0.8 per cent, *Aeromonas* 1.6 per cent and miscellaneous 17 per cent, being classified according to Shewan (1954) and Shewan, Hobbs and Hodgkiss (1960a, 1960b). During ice storage the composition of the flora changed and irrespective of the initial composition the final flora at the advanced stages of spoilage consisted mainly of gram-negative rods of genus *Achromobacter*. Quantitatively the bacterial counts of prawns of different marine species were generally higher than those of teleost fish. Gram-negative rods predominated in the fresh prawns accounting for more than 90 to 95 per cent of the flora of which *Vibrio* predominated. The picture was slightly different with prawns of backwater origin in which presence of *Aeromonas* (10 to 69 per cent) was noticed. During prolonged storage in ice, the predominating flora both in the marine and backwater prawns were found to consist mainly of non-motile gram-negative rods or coccoids belonging to the *Achromobacter* genus (72 to 89 per cent of flora at the final stage).

During frozen storage at −12.2°C (10°F) and at −23.3°C (−10°F) of the individually quick-frozen sardines it was observed that at −12.2°C (10°F) after an initial fall, the bacterial count continued to rise. But when stored at −23.3°C (−10°F) the count decreased continuously (fig 1).

The results of a typical study with backwater prawns which were frozen fresh without icing and after holding in ice for a few days showed that while in the case of uniced and one-day and two-day ice-stored samples, the bacterial count steadily decreased, in the case of three-day and four-day iced samples the count increased after falling for the six weeks of storage at 12.2°C (+10°F) (fig 2).

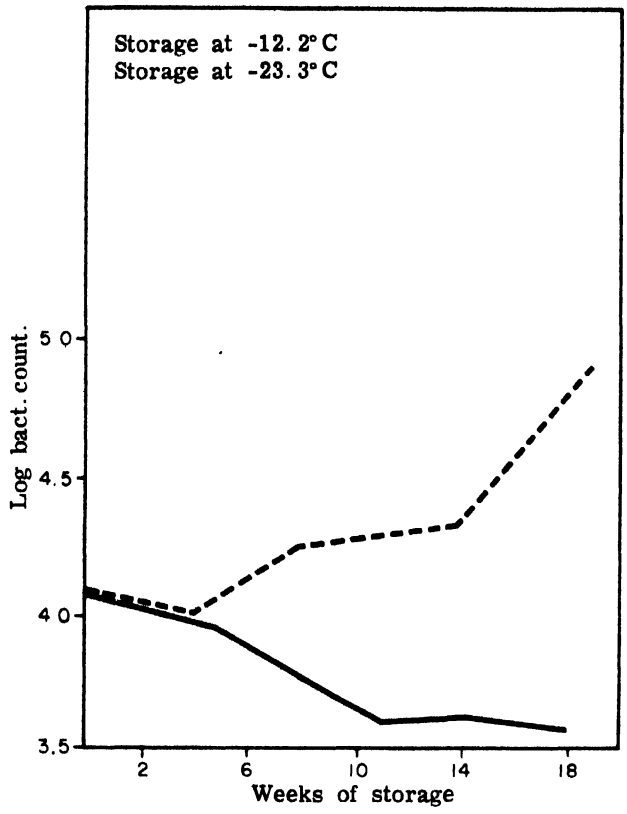


Fig 1. Bacterial growth curve for frozen sardines

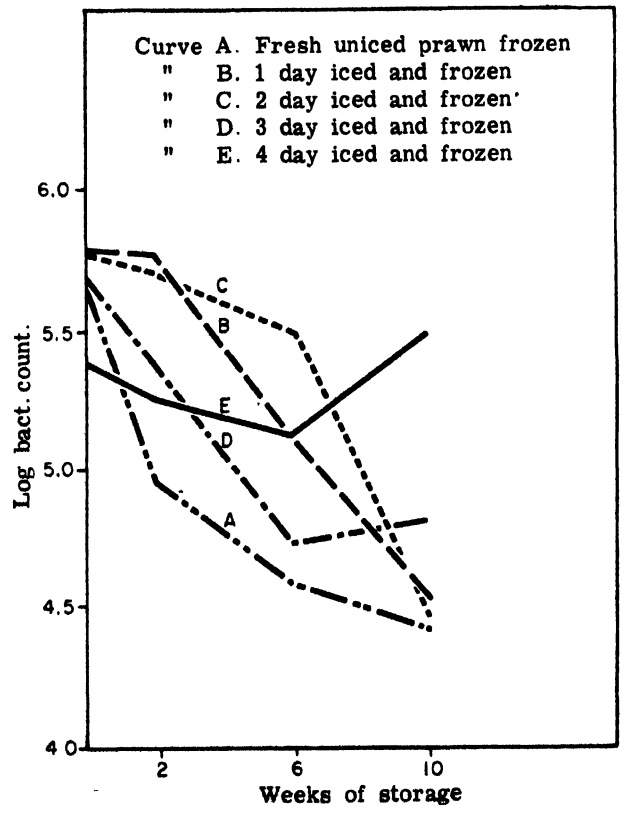


Fig 2. Bacterial growth curve for frozen prawns

FREEZING ASPECTS

Conditions of freezing

The investigations carried out on the effect of initial temperature of load on thermal-arrest time during freezing indicated that the higher the initial temperature of the load the lesser the time in which material passes from 0° to −5°C (32° to 23°F). Long (1958) had also made similar observations. Results obtained in one of the typical experiments with peeled-deveined (P & D) prawns are given in table 5.

TABLE 5. INFLUENCE OF INITIAL TEMPERATURE OF THE LOAD ON THERMAL ARREST TIME

(Block of 2.3 kg P & D prawns, 5 cm thick, frozen in contact plate freezer at −30°C)

Initial temperature of material (°C)	*Time required to pass through 0° to −5°C (min)*
4	92
86	80
10	73
24.4	60
26.6	52

The observation has significance in relation to the fact that longer time to pass from 0° to −5°C (32° to 23°F) should cause more drip-loss on thawing with consequent effect on quality. However, adverse effect in this case has to be balanced against accelerated deterioration when fish is kept at higher temperature before freezing.

The freezing rates as obtained in commercial plate freezer compared with that obtained in air-blast freezer were determined (fig 3). Effect of initial temperature of fish on the rate of freezing is also demonstrated.

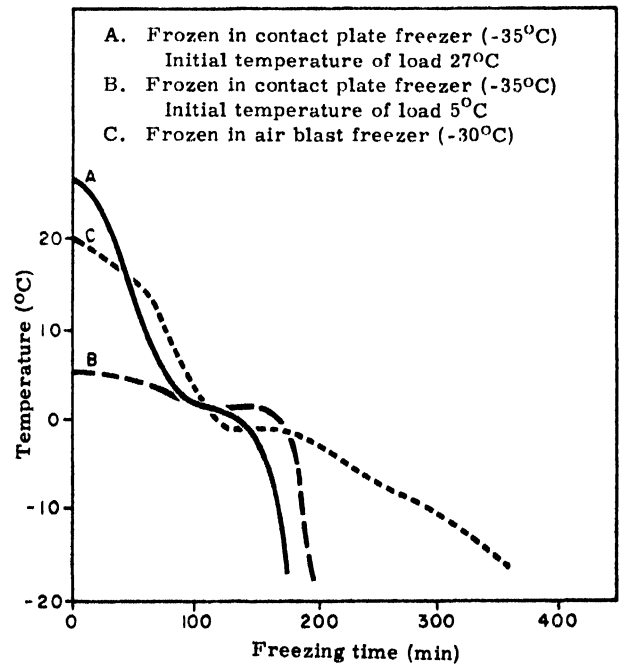


Fig 3. Freezing rates of 5 cm thick peeled-deveined prawn block (2 to 3 kg)

Investigations on glazes for frozen prawns

Investigations on pre-dip treatment and glazing were carried out on frozen prawns with a view to improving the drained weight and the organoleptic quality especially colour and flavour of the thawed material. Pre-dipping for 10 min in 4 per cent sodium hexametaphosphate or sodium tripolyphosphate yielded encouraging results in the case of quick-frozen peeled-deveined prawns (table 6).

TABLE 6. EFFECT OF PHOSPHATE ON DRAINED WEIGHT AND DRIP CHARACTERISTICS OF FROZEN PEELED-DEVEINED PRAWNS (*M. dobsoni*)

Characteristics	*Control*	*Treated sodium hexa-metaphosphate*	*Sodium tripoly phosphate*
Moisture content (%)	79.85	81.12	81.19
Drained weight (%)	90.0	94.0	96.0
Drip volume (ml/100 g)	9.6	8.1	6.6
Total nitrogen in thaw-drip (mg/100 g)	156.4	131.0	102.0

The beneficial use of polyphosphate in reducing the thaw-drip and in improving the taste panel score of frozen fishes was also observed by Canadian and Japanese workers (Boyd and Southcott, 1965; Chalker and MacCallum, 1965; Dyer *et al.*, 1964; MacCallum *et al.*, 1964; Tanikawa, Akiba and Shitamori, 1963).

Experiments have also shown that providing a glaze with a solution of 0.5 per cent sugar and 0.5 per cent NaCl would improve the colour and flavour of headless and peeled-deveined prawns compared to that with water only. Ascorbic acid water glaze was not found to be effective in retarding the oxidation of fat in this fish although encouraging results were obtained by Tarr (1948) for cod, by Bramsnaes and Sorensen (1960) for frozen trout, and by Sawant and Magar (1961) for other Indian fish.

Quick freezing by the contact plate freezer (−40°C, −40°F) as was employed for sardines, prawns of several species and seer (*Scomberomorus commerson*) fish has been found to produce a frozen product of better quality as compared to that obtained by slow freezing (−12°C, 10°F) in still air. Slow frozen seer fish held at −12.2°C (10°F) for eight weeks was organoleptically rated inferior being tougher in consistency and fibrous and exuding a larger volume of drip loss (table 7).

The extent of lipid oxidation and hydrolysis occurring during frozen storage in IQF sardines prepared from fresh and ice-stored samples is shown in table 8.

TABLE 7. QUALITY OF FROZEN SEER (*Scomberomorus commerson*) FISH FILLETS STORED AT −23.3°C

Sample no.	*Storage period (weeks)*	*Volume of drip*		*Organoleptic score*	
		Quick frozen	*Slow frozen*	*Quick frozen*	*Slow frozen*
		(ml/100 g)			
1	4	3.9	5.6	12	10
	8	4.7	6.0	8	7
2	8	3.6	5.1	10	7

TABLE 8. RANCIDITY DEVELOPMENT IN IQF SARDINES (*Sardinella longiceps*) HELD AT −23.3°C

Particulars	*FFA*		*TBA value**	
	Fresh frozen	*Four-day iced frozen*	*Fresh frozen*	*Four-day iced frozen*
	(% oleic acid)			
Before freezing	1.22	2.80	3.10	11.10
On freezing	5.55	10.20	6.30	9.50
3 weeks at −23.3°C	5.55	8.20	6.1	11.9
6 weeks at −23.3°C	5.90	7.90	10.9	—
9 weeks at −23.3°C	19.5	10.50	11.6	19.60

* Thiobarbituric acid value determined according to Tarladgis *et al.* (1960).

FROZEN FISH AND SHELLFISH

Shelf-life of certain species

One of the important changes in frozen fish during prolonged storage which lowers the organoleptic quality is the denaturation of the protein.

Experiments were undertaken at the Institute with frozen sardines and prawns stored at different temperatures. Raw fish used in these experiments were kept in ice storage for a varying number of days prior to freezing. Denaturation in frozen fish is accompanied by decrease in extractability of salt soluble proteins (Reay, 1933) which criterion was employed to follow its course (Dyer, French and Snow, 1950). The longer the fish was kept in ice storage before freezing, the greater was the degree of protein denaturation. This was generally true for all commercial species of prawns held as headless or peeled-deveined and other fish. The ATP-ase activity of the muscle (Dubois and Potter, 1943) was also found to be useful in following this change in frozen fish (table 9).

TABLE 9. ATP-ASE ACTIVITY OF THE MUSCLE OF PEELED-DEVEINED PRAWNS (*P. indicus*) IN FROZEN STORAGE AT −23.3°C FOR TWO WEEKS

Sample	*ATP-ase activity**
Uniced freshly frozen	33.3
Iced 1 day and frozen	24.8
Iced 3 days and frozen	20.4
Iced 5 days and frozen	20.3

* μgp which would have been liberated by extract containing 100 mg tissue in 15 min of incubation at 37°C.

Table 10 gives an account of the approximate shelf-life of some of the common tropical fish in India, held frozen under various conditions of handling, freezing and storage.

It was also observed that at higher storage temperatures denaturation occurred at a faster rate as shown with IQF sardines held at −22.2°C (−8°F) and −23.3°C (−10°F) (figs 4 and 5). In the case of block-frozen sardines, denaturation was slower when compared with IQF samples (fig 6). Consequently on denaturation, more drip loss is exuded in fish proportional to the length of storage in ice prior to freezing. There was also a simultaneous increase in the loss of total nitrogen and free α-amino nitrogen through the drip (table 11).

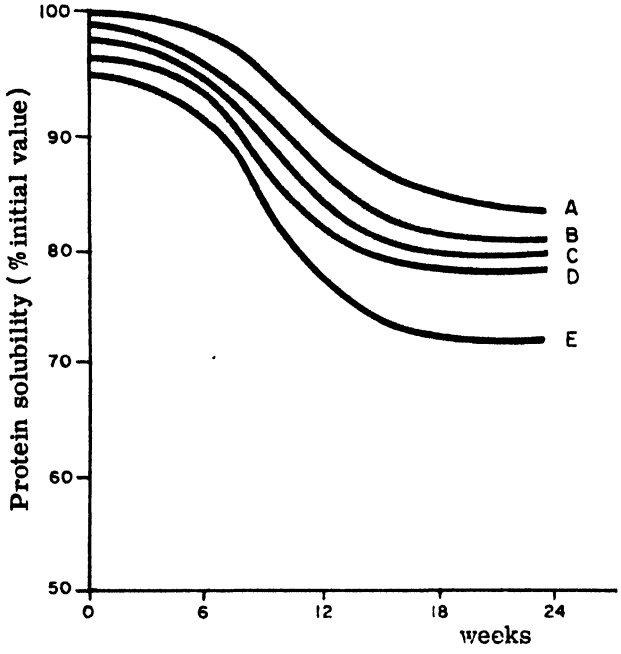


Fig 4. Protein denaturation in IQF sardines at −23°C

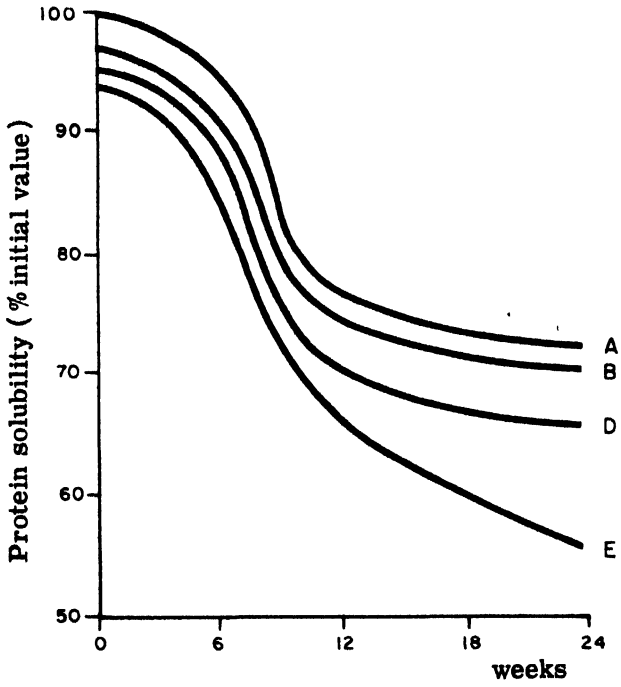


Fig 5. Protein denaturation in IQF sardines at −12.2°C

Fatty fishes like sardine, mackerel and seer fish underwent changes due to changes in lipids during storage in ice and also during frozen storage. The effect of ice storage of the fish on the subsequent development of rancidity, during frozen storage was investigated with these varieties of fish. The shelf-life of quick-frozen oil sardine was influenced by the fat content which shows seasonal variations round the year (table 12).

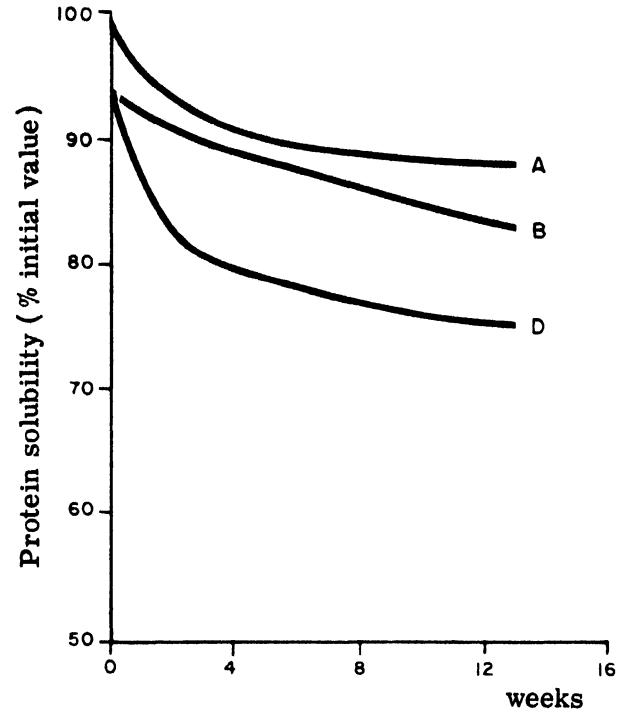


Fig 6. Protein denaturation in block frozen sardines at −23.3°C
A, *fish freshly frozen;* B, *fish iced one day and frozen;* C, *fish iced two days and frozen;* D, *fish iced three days and frozen;* E, *fish iced four days and frozen*

Transport

Temperature measurements were made during the road transport of frozen prawns in insulated trucks from cold storages to wharfs prior to shipment. The ambient temperature was between 23° to 25°C (73.4° to 77°F). The trucks employed were of insulated type [3.8 cm (1½ in) thermocole insulation at the sides and bottom and 5 cm (2 in) at the roof]. Ten thermocouples were fixed at different points in the test blocks in a master carton [10×2.3 kg, 5 cm (2 in) thick prawn blocks]. During the loading (usually lasted 30 to 60 min) the surface (top and sides) showed a rise of 4 degC (7 degF) from initial temperature of −14°C (7°F), while the centre of the carton rose by 1.5 degC (2.7 degF). The overall temperature rise at the surface was 9 deg to 10 degC (16 deg to 18 degF) and at centre was 3.5 degC (6 degF) at the end of a 5 h journey. The temperature distribution in the carton against time of transport is given in fig 7.

Experiments on the effect of intermittent fluctuation in temperatures higher than −23.3°C (−10°F) on the quality of frozen peeled-deveined prawns and headless prawns (table 13) demonstrated that although physical and chemical changes observed on the material stored continuously at −17.8°C (0°F) and −23.3°C (−10°F) were not significant for about 10 months, the rate of quality deterioration on similar samples subjected to higher storage temperature for periods even from one to two weeks was fast and became appreciable within four to six months.

TABLE 10. SHELF LIFE OF CERTAIN FROZEN FISH AND SHELLFISH OF COMMERCIAL IMPORTANCE IN INDIA

Species	*Pre-processing treatments*	*Type of pack; round or fillets*	*Whether frozen in blocks or individually*	*Whether wrapped*	*Whether glazed*	*Mode of freezing*	*Storage temperature*	*Shelf life (weeks)*	*Signs of Spoilage*
Oil sardine (*Sardinella longiceps*) (fat = 15.3 per cent MFB)	Fresh	Round	Individual	—	Not glazed	Quick (Contact plate freezer at −40°C)	−12.2°C	20	Belly bursting, rancid flavours and tough texture
	1-day iced	,,	,,	—	,,	,,	−12.2°C	16	,, ,,
	2-day iced	,,	,,	—	,,	,,	−12.2°C	13	,, ,,
	3-day iced	,,	,,	—	,,	,,	−12.2°C	10	,, ,,
	4-day iced	,,	,,	—	,,	,,	−12.2°C	6	,, ,,
	Fresh	,,	,,	—	,,	,,	−23.3°C	20	,, ,,
	1-day iced	,,	,,	—	,,	,,	−23.3°C	20	,, ,,
	2-day iced	,,	,,	—	,,	,,	−23.3°C	16	,, ,,
	3-day iced	,,	,,	—	,,	,,	−23.3°C	12	,, ,,
	4-day iced	,,	,,	—	,,	,,	−23.3°C	7	,, ,,
	Fresh	Round	Block	—	Glazed	Quick	−23.3°C	20	,, ,,
	1-day iced	,,	,,	—	,,	,,	−23.3°C	20	,, ,,
	3-day iced	,,	,,	—	,,	,,	−23.3°C	18	,, ,,
	5-day iced	,,	,,	—	,,	,,	−23.3°C	10	,, ,,
Seer fish (*Scomberomorus commerson*)	Fresh gutted fish	Fillets	Individual	Polythene lined	Not glazed	Quick	−23.3°C	10	Fading of colour, chalkiness, texture loss
	2-day iced	,,	,,	,,	,,	,,	−23.3°C	8	,, ,,
	5-day iced	,,	,,	,,	,,	,,	−23.3°C	6	,, ,,
	Fresh gutted fish	,,	,,	,,	,,	Slow	−23.3°C	10	,, ,,
	2-day iced	,,	,,	,,	,,	,,	−23.3°C	8	,, ,,
	5-day iced	,,	,,	,,	,,	,,	−23.3°C	6	,, ,,
Tuna (blue marlin) (*Makaira nigricans*)	Fresh	Fillets (2.5 cm thick)	,,	,,	,,	Quick	−20.5°C	12	Fading of colour, fibrous texture
	,,	,,	,,	,,	Glazed	,,	−20.5°C	16	,, ,,
Tuna (white marlin) (*Makaira indica*)	Fresh	,,	Block	No lining	Not glazed	,,	−20.5°C	8	,, ,,
	,,	,,	,,	Polythene lined	Glazed	,,	−20.5°C	8	,, ,,
	,,	,,	Individual	No lining	Not glazed	,,	−20.5°C	6	,, ,,
	,,	,,	,,	Polythene lined	Glazed	,,	−20.5°C	8	,, ,,
Caranx (*Caranx melampygus*)	Fresh	Fillets	Individual	Polythene lined	Glazed	Slow	−17.8°C	12	Off-flavour, and texture loss
	,,	,,	,,	No lining	Unglazed	,,	−17.8°C	8	Desiccation, off-flavour
	,,	,,	,,	Polythene lined	Glazed	Quick	−17.8°C	12	Off-flavour, and texture loss
	,,	,,	,,	No lining	Unglazed	,,	−17.8°C	8	Desiccation, texture loss
Catla (*Johnius* sp.)	Fresh	,,	,,	No lining	Unglazed	Quick	−20.5°C	8	Desiccation, hard texture
	,,	,,	,,	Polythene lined	Glazed	,,	−20.5°C	12	Off-flavour, hard texture
Mackerel (*Rastrelliger kanagurta*)	Fresh	Round	Individual block	Polythene lined	Glazed	Quick	−20.5°C	16	Rancid flavours and hard texture

TABLE 10. SHELF LIFE OF CERTAIN FROZEN FISH AND SHELLFISH OF COMMERCIAL IMPORTANCE IN INDIA (*cont.*)

Species	*Pre-processing treatments*	*Type of pack; round or fillets*	*Whether frozen in blocks or individually*	*Whether wrapped*	*Whether glazed*	*Mode of freezing*	*Storage temperature*	*Shelf life (weeks)*	*Signs of spoilage*
Prawns (*Penaeus indicus*) (Marine)	Fresh	Headless	Block	Polythene lined	Glazed	Quick	−23.3°C	28	Fading of colour, off-flavour and odour, texture loss, black spots
	1-day iced	,,	,,	,,	,,	,,	−23.3°C	24	,, ,,
	2-day iced	,,	,,	,,	,,	,,	−23.3°C	20	,, ,,
	3-day iced	,,	,,	,,	,,	,,	−23.3°C	20	,, ,,
(*Penaeus indicus*) (Marine) (130 up)	Fresh	P & D	,,	,,	,,	,,	−23.3°C	40	Fading of colour, off-flavour and odour, texture loss
	1-day iced	,,	,,	,,	,,	,,	−23.3°C	40	,, ,,
	2-day iced	,,	,,	,,	,,	,,	−23.3°C	38	,, ,,
	3-day iced	,,	,,	,,	,,	,,	−23.3°C	32	,, ,,
	4-day iced	,,	,,	,,	,,	,,	−23.3°C	28	,, ,,
(*Penaeus indicus*) (backwater)	Fresh	Butterfly pack	,,	,,	,,	,,	−23.3°C	36	Fading of colour, off-flavour and odour, texture loss
	,,	Fantail	,,	,,	,,	,,	−23.3°C	36	,, ,,
(*Penaeus indicus*) (backwater)	Fresh	P & D	,,	,,	,,	,,	−23.3°C	36	,, ,,
	1-day iced	,,	,,	,,	,,	,,	−23.3°C	32	,, ,,
	3-day iced	,,	,,	,,	,,	,,	−23.3°C	24	,, ,,
	5-day iced	,,	,,	,,	,,	,,	−23.3°C	20	,, ,,
(*Metapenaeus affinis*)	Fresh	Headless	,,	,,	,,	,,	−23.3°C	24	,, ,, and black spots
	,,	P & D	,,	,,	,,	,,	−23.3°C	36	,, ,,
(*Metapenaeus dobsoni*)	,,	,,	,,	,,	,,	,,	−23.3°C	40	,, ,,
(*Microbrachium rosenbergi*)	,,	Headless	,,	,,	,,	,,	−23.3°C	28	,, ,,
(*Metapenaeus monodon*)	,,	,,	,,	,,	,,	,,	−23.3°C	28	,, ,,
Shellfish other than prawns									
Lobster (*Panulirus burgeri*)	,,	Lobster tail	Individual	,,	Not glazed	,,	−23.3°C	20	Yellow discolouration, off-flavours, texture loss
Clam (*Villorita cornucopia*)	,,	Meat	Block	,,	,,	,,	−23.3°C	28	Surface dehydration, bitter flavour, rubbery texture
	1-day iced	,,	,,	,,	,,	,,	−23.3°C	28	,, ,,
	2-day iced	,,	,,	,,	,,	,,	−23.3°C	28	,, ,,
	6-day iced	,,	,,	,,	,,	,,	−23.3°C	20	,, ,,
	8-day iced	,,	,,	,,	,,	,,	−23.3°C	8	,, ,,
Mussel (*Mytilus viridis*)	Fresh	,,	,,	,,	,,	,,	−23.3°C	24	Hard texture, dry fish taste
	1-day iced	,,	,,	,,	,,	,,	−23.3°C	20	,, ,,
	4-day iced	,,	,,	,,	,,	,,	−23.3°C	20	,, ,,
	7-day iced	,,	,,	,,	,,	,,	−23.3°C	12	,, ,,

TABLE 11. DRIP CHARACTERISTICS OF BLOCK FROZEN SARDINE (*Sardinella longiceps*) (450 G FISH AND 450 ML WATER) FROZEN AT −40°C AND STORED AT −23.3°C FOR SIX WEEKS

Days in ice before freezing	*Volume of drip (ml/100 g fish)*	*Total nitrogen (mg/100 g fish)*	*Free α-amino N (mg/100 g fish)*	*Colour of drip*
0	29.0	73.0	8.5	Light brown
1	27.8	74.8	19.1	Brownish
3	41.1	92.1	43.8	Dark brown
5	45.2	148.0	56.7	Dark brown

TABLE 12. SHELF LIFE OF QUICK-FROZEN OIL SARDINE (*Sardinella longiceps*) IN RELATION TO ITS FAT CONTENT AT −23.3°C

Fat (MFB) (%)	*FFA on freezing (% oleic acid)*	*Peroxide value (meq/kg fat)*			*Shelf life (weeks)*
		At the end of storage period	*On freezing*	*End of storage period*	
10.3	2.17	19.46	1.2	10.98	20
15.3	2.32	12.7	1.2	38.15	16
22.0	1.37	2.11	0.0	43.18	12
32.1	2.77	3.77	8.55	52.1	12
35.2	1.76	3.49	3.15	39.13	10
40.4	0.64	3.09	2.82	47.95	8

TABLE 13. CHANGES IN PROTEIN DENATURATION AND DRIP CHARACTERISTICS OF FROZEN PEELED AND DEVEINED PRAWNS (*M. dobsoni*) SUBJECTED TO FLUCTUATING TEMPERATURE DURING STORAGE (TOTAL TIME OF STORAGE—SIX MONTHS)

Particulars	*Drip characteristics*							
	Drip volume (ml/100 g drained wt)		*TVN (mg/100 g drained wt)*		*α-NH_2 N (mg/100 g drained wt)*		*Percentage salt soluble protein*	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*
1. Stored at −23.3°C	56	86	1.52	1.94	3.04	9.22	88.4	78.56
2. Held at −17.7°C for 2 weeks and then at −23.3°C	62	107	1.86	2.26	3.62	14.21	—	70.70
3. Held at −17.7°C for 4 weeks and then at −23.3°C	68	118	1.89	2.89	3.60	14.32	84.2	70.0
4. Held at −12.2°C for 2 weeks and then at −23.3°C	64	115	2.50	3.21	3.75	15.55	79.58	65.50
5. Held at −12.2°C for 4 weeks and then at −23.3°C	72	123	2.71	3.75	4.01	16.06	80.07	62.90

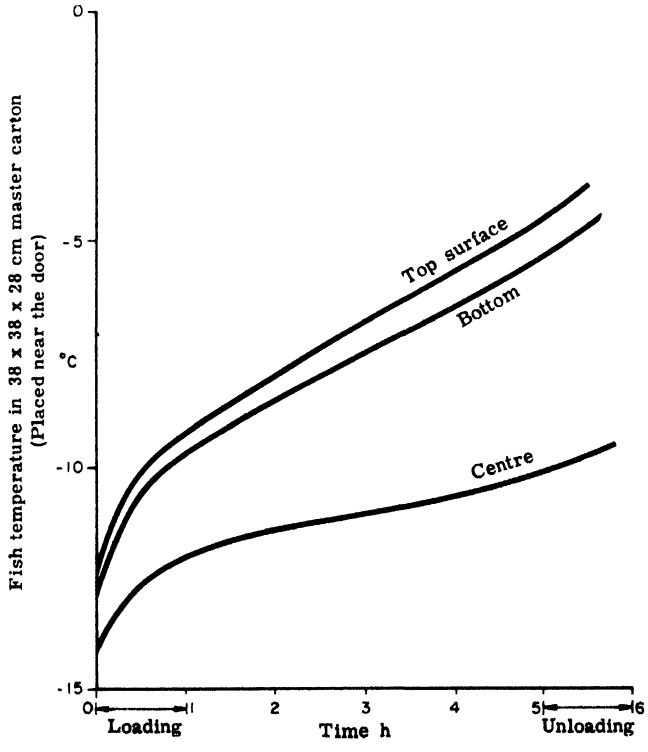


Fig 7. Road transport of frozen fish in insulated van (ambient temperature 23° to 25°C)

ADDENDUM

Refrigerated sea water in the preservation of tropical fish

A. N. Bose adds: Refrigerated sea-water (RSW) as a refrigerant either for pre-chilling prior to freezing or for storage of fish has not been employed on a commercial scale in India. However, a number of experiments have been carried out to assess the suitability of RSW in handling of certain tropical fish and shellfish. Work carried out at this Institute showed that some species of prawns (*M. dobsoni*) held in round conditions in RSW (0° to 1.1°C, 32° to 34°F) were superior to those stored in crushed ice with regard to general appearance, firmness of meat, absence of external damage to shell and flesh and lower incidence of black spots. In a closed system of RSW and prawns (1 : 1), there was a progressive decrease in total solids with the time of storage, but this loss was much less than in prawns held in ice for the same period. Slightly better retention of water-soluble constituents—NPN, α-amino N and ortho-phosphate—was observed in RSW-stored prawns. Studies on shelf-life of prawns in RSW have thus shown that the laborious process of preparation and icing of prawns at sea might well be eliminated by use of RSW in which prawns could be stored in round condition. Particularly in season of glut, this method of chilling of prawns could be a solution to the problem of their short-term preservation prior to processing in canneries.

In the case of round and eviscerated sardine (*Sardinella longiceps*) stored in RSW, notable gain in total weight and mineral content (Na^+) occurred, the increase being greater for eviscerated fish. The loss of total nitrogen from fish on the other hand was also higher for gutted fish which might indicate that storage of whole fish is to be preferred over gutted fish for short periods. The shelf-life of oil sardine (fat content = 5.8 per cent) in RSW (0° to 1.1°C, 32° to 34°F) was found to be three to four days. The comparative study showed that RSW-stored fish spoiled less rapidly than fish held in ice.

Experiments were also conducted on the use of chlortetracycline (CTC) in enhancing the storage life of RSW-held fish. Although the beneficial effect of CTC in RSW is much less pronounced compared to CTC plus ice, dipping in CTC (25 to 50 ppm) solution prior to storage of sardine in RSW had the advantage of bringing down the incidence of characteristic foul odours. CTC treatment delayed the spoilage of gutted fish in RSW as judged bacteriologically and organoleptically.

References

BOYD, J M and SOUTHCOTT, B A *J. Fish. Res. Bd Can.*, **22**, 53. 1965

BRAMSNAES, F and SORENSEN, H C *Proc. X Int. Congr.* 1960 *Refrig.*, Copenhagen, **3**, 247.

CHALKER, D A and MACCALLUM, W A *J. Fish. Res. Bd Can.*, 1965 **22**, 783.

DUBOIS, K P and POTTER, V K *J. biol. Chem.*, **150**, 185. 1943

DYER, W J, FRENCH, H V and SNOW, J M *J. Fish. Res. Bd* 1950 *Can.*, **7**, 585.

DYER, W J, BROCKERHOFF, H, HOYLE, R J and FRASER, D I 1964 *Ibid.*, **21**, 101.

GOVINDAN, T K *Indian J. Fish.*, **9**, 7. 1962

LISTON, J *J. gen. Microbiol.*, **16**, 205. 1957

LONG, R A K *J. Sci. Fd Agric.*, **9**, 78. 1958

MACCALLUM, W A, CHALKER, DOROTHY A, LAUDER, J T, 1964 ODENSE, P H and IDLER, D R Polyphosphate treatment of frozen cod. 3. Taste panel evaluation, chemical assessment, and thaw drip in once-frozen Newfoundland trap-caught cod. *J. Fish. Res. Bd Can.*, **21**(6), 1397.

MEJBAUM, W *Hoppe-Seyler's Z. physiol. Chem.*, **258**, 117. 1939

PAWAR, S S and MAGAR, N G *J. Fd Sci.*, **31**, 87. 1966

RAJENDRANATHAN NAIR, M and BOSE, A N In *The Technology* 1965 *of Fish Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 68.

REAY, G A *J. Soc. chem. Ind.*, **52**, 265. 1933

SAWANT, P L and MAGAR, N G *Fd Technol., Champaign*, **15**, 1961 347.

SHEWAN, J M *Nature, Lond.*, **173**, 208. 1954

SHEWAN, J M, HOBBS, G and HODGKISS, W *J. appl. Bact.*, 1960a **23**, 379.

SHEWAN, J M, HOBBS, G and HODGKISS, W *Ibid.*, **23**, 463. 1960b

SILBERT, G and SCHMIDT, A *Biochem. Z.*, **334**, 96. 1961

SUSAMMA, J, MAHADOVA IYER, K, RAJENDRANATHAN NAIR, M 1962 and PILLAI, V K *Indian J. Fish.*, **9**, 97.

TANIKAWA, E, AKIBA, M and SHITAMORI, A *Fd Technol.*, 1963 *Champaign*, **17**, 87.

TARLADGIS, B G, WETTS, B M, YOUNATHAN, M T and 1960 DUGAN, L *J. Am. Oil Chem. Soc.*, **37**, 44.

TARR, H L A *J. Fish. Res. Bd Can.*, **7**, 237. 1948

TOMLINSON, N, GEIGER, S E and ROBERTS, EVE *Prog. Rep.* 1962 *Pacif. Cst Stns*, **114**, 19.

TOMLINSON, N, JONAS, R E E and GEIGER, S E *J. Fish. Res.* 1963 *Bd Can.*, **20**, 1145.

VELANKAR, N K, GOVINDAN, T K, MAHADEVA IYER, K and 1961a APPUKUTTAN, P N *J. scient. ind. Res.*, **20D**, 189.

VELANKAR, N K, GOVINDAN, T K, APPUKUTTAN, P N and 1961b MAHADEVA IYER, K *Indian J. Fish.*, **8**, 241.

Factors Influencing Quality of Frozen Fish at Sea in Subtropical and Tropical Areas

by E. Kordyl and Z. Karnicki

Factors influencing quality of frozen fish at sea in subtropical and tropical areas

Since 1963 Polish fisheries have been expanding and developing the catches in the fishing grounds of the West African shelf. In these fishing operations two types of freezing trawlers are used: 600 D.W. (B-23) and 1300 D.W. (B-18) vessels.

Among the fundamental requirements of obtaining frozen fish of good quality from the fishing grounds of subtropical and tropical areas the most important is the conservation of fish from the moment it is taken out of the sea to its being frozen. The *post-mortem* changes in fish in those regions are much more rapid than in moderate or subarctic climates. For instance, large Spanish mackerel (*Scomber colias*) left on deck in the temperature of about 30°C (86°F) and exposed to sun rays, showed evident deterioration of quality within 1 h in the outer layer of the fish pile, and within 2.5 to 3 h in the middle of the pile. After 6 to 8 h an evident degree of spoilage was noted. Cape hake (*Merluccius capensis*) from the region of Angola showed autolytic changes after 2 to 3 h in the temperature of 14°C (57.2°F).

The experiments with application of sea water cooled down to about 0°C (32°F) showed the decrease of the rate of *post-mortem* changes in the fish so that the first signs of deterioration of quality were observed in the fish after 24 to 36 h, while in fish kept in non-cooled water at 14°C (57.2°F) and 20°C (68°F) they appeared after 5 to 6 h.

The estimation of quality of frozen fish after five months storage at −25°C (−13°F) showed that in order to obtain a product of good quality it is necessary to almost halve the time of storage of wet fish in refrigerated sea-water tanks, i.e. to reduce it to about 12 h. The determination of trimethylamine and total volatile bases did not show any regularity or correlation with organoleptic changes.

The application of refrigerated sea-water for pre-chilling of fish in tropical areas brings evident effects in improvement of quality of frozen fish. This, however, still requires more detailed investigations in order to establish improved technique and technology of the method.

Facteurs affectant la qualité du poisson congelé en mer dans les zones subtropicales et tropicales

Depuis 1963, les pêches polonaises intensifient leur exploitation des fonds de pêche au large du plateau continental de l'Afrique de l'Ouest, utilisant à cette fin deux types de navires: l'ancien B-23 et le nouveau B-18.

Pour obtenir du poisson de bonne qualité devant être congelé en zone tropicale ou subtropicale, il est indispensable d'assurer le maintien de la fraîcheur du poisson du moment où il est amené à bord jusqu'à sa congélation. A des températures élevées (30°C, 86°F), une nette altération survient en 2 ou 3 heures. L'étude a porté sur les principales espèces d'intérêt commercial: maquereau espagnol (*Scomber colias*) et merlu du Cap (*Merluccius capensis*).

Les essais faits avec de l'eau de mer réfrigérée à 0°C (32°F) ont révélé un net ralentissement des modifications *post-mortem*: les premiers signes d'altération n'ont pas été observés avant 24 à 36 heures, alors que chez le poisson conservé dans de l'eau de mer non réfrigérée ils sont apparus au bout de 5 à 6 heures.

Il est démontré que pour obtenir un poisson congelé qui soit de bonne qualité après décongélation, la durée de la conservation en eau de mer réfrigérée doit être ramenée à 12 heures environ.

Les modifications de la teneur en triméthylamine et en azote basique volatil total n'étaient pas régulières et ne révélaient pas de corrélation avec les changements organoleptiques.

Si l'emploi de l'eau de mer réfrigérée pour le prérefroidissement du poisson dans les zones tropicales est très prometteur, il reste beaucoup à faire pour améliorer cette technique.

Factores que influyen en la calidad del pescado congelado en el mar en las zonas subtropicales y tropicales

A partir de 1963 la pesca en Polonia ha seguido ampliando sus actividades en los caladeros frente a la plataforma continental de Africa Occidental. Se han empleado dos clases de barcos de pesca, un tipo más antiguo el B-23, y otro más moderno el B-18.

Uno de los requisitos fundamentales para obtener pescado de buena calidad para congelarlo en las zonas tropicales y subtropicales consiste en mantener su frescura desde el momento en que se le saca del mar hasta que se le congela. A altas temperaturas (30°C, 86°F) se produce una descomposición notable en el espacio de dos a tres horas. Se examinaron las especies comerciales más importantes tales como la caballa (*Scomber colias*) y la merluza sudafricana (*Merluccius capensis*).

Los experimentos con agua de mar refrigerada a la temperatura de 0°C (32°F) mostraron una sensible disminución de los cambios post-mortem, de modo que los primeros signos de alteración del pescado sólo se observaron transcurridas 24 a 36 horas. En cambio, el pescado que se mantuvo en agua de mar no refrigerada reveló esas mismas señales de descomposición al cabo de 5 a 6 horas.

Para producir pescado congelado de buena calidad al descongelarlo, las pruebas revelaron que sería preciso reducir a 12 horas el tiempo que se mantenía el pescado en agua de mar refrigerada.

La descomposición de trimetilamina (TMA) y de bases volátiles totales (BVT) no mostró regularidad ni tampoco hubo correlación con cambios organolépticos.

Aunque el empleo de agua de mar refrigerada para precongelar el pescado en las zonas tropicales es muy prometedor, queda todavía bastante por hacer para mejorar la técnica de este método.

THE Polish fisheries have been following a planned expansion of their fishing fleet to cope with the trend to "distant fishing". The Polish factory fleet have been operating since 1960 in the North-west Atlantic and since 1963 in the grounds of the West African shelf.

The first experimental cruises of freezing trawlers to the fishing grounds situated along the coasts of Mauritania and Senegal showed the possibility of good fishing, particularly in the first and fourth quarters of the year. High temperatures prevailing there, however, make the discharging of wet fish on deck very difficult, and additional equipment is therefore necessary for pre-chilling of fish from the moment it is taken on board until it is frozen. While there are no adequate vessels available to the technical staff of the Sea Fisheries Institute, they participate in commercial fishing trips to make observations and to carry out experiments aimed at the introduction of necessary equipment, and make recommendations to ensure that the supply of frozen fish on land is of suitable quality for processing and marketing. Therefore the observations and investigations carried out

aboard commercial fishing vessels aim to review the cause of rapid deterioration of fish at high temperatures and to establish means of counteracting this.

An emphasis has been laid on pre-chilling of fish by refrigerated sea-water (RSW). On the basis of the opinions of many authors at the OECD Meeting on Fish Technology held at Scheveningen in 1964 by the Organization for Economic Cooperation and Development (OECD, 1965), as well as the results of Soviet experiments carried out on a commercial scale (Anon., 1964), it is assumed that the pre-chilling method should be the most useful for application under tropical conditions.

TRAWLER OPERATION IN THE WEST AFRICAN SHELF REGION

Early ships (B-23 type)

These are modernized herring trawlers equipped with a large freezing capacity and refrigerated holds. They are used here during periods of low production in the North Sea. They possess flake ice machines with adequate ice storage and plate freezers. A storage room for wet fish is available as well as a meal plant for the disposal of offal.

There is no provision for filleting; therefore, as a rule, whole fish is frozen head-on or headless and either round or gutted.

Later ships (B-18 type)

On one of the later trawlers (B-18 type) tanks were installed for 5 t each. They also have flake ice machines, various Baader machines for heading and cleaning, horizontal plate freezers, air-blast freezers, refrigerated holds for storage, as well as a fish meal plant for the disposal of offal.

The fish is processed in a fashion similar to the above vessels but some of the larger fish are cut into pieces. Flake ice is used for the pre-chilling of large fish which cannot be pre-chilled in RSW tanks, as they are difficult to remove with the conventional elevators. The rate of chilling using a ratio of 1 : 1.5 fish to water from a temperature of 25° to 28°C (77° to 82°F) to 5° to 6°C (41° to 43°F) takes 3 to 4 h. The fish is delivered directly from the deck to the tanks. The emptying of the tanks is accomplished by elevators in the tanks. After each load the tank is cleaned and fresh water is used. The time the fish is in the tank does not exceed 12 h with temperature maintained at 5° to 6°C (41° to 43°F), and 15 h at a temperature of 3° to 4°C (37° to 39°F).

FISHING GROUNDS OF THE WEST AFRICAN SHELF EXPLOITED BY THE POLISH FISHERIES

Fishing areas

In the years 1963 to 1965 Polish catches on the West African shelf were concentrated mainly in the north along the coasts of Mauritania, Senegal and Gambia. In 1966 these landings amounted to approximately 43,000 t, of which Mauritania produced 21,500, Senegal 20,000 and Angola 1,500 t.

Main species

In the fishing grounds of Mauritania and Senegal mainly the following species were captured:

Spanish mackerel (*Scomber colias*)
Horse mackerel (*Trachurus trachurus*)
Horse mackerel—yellow (*Caranx ronchus*)
Sea bream (*Pagellus* spp.)
Large-eyed dentex (*Dentex* spp., *Lichia vardigo*)
Blue fish (*Pomatomus saltator*)

and some others of minor commercial importance. There is landed quite often an incidental catch of small fish, such as small horse mackerel, sardine (*Sardinella aurita*), small fish [*Brachydeuterus* (*otoperca*) *auritus*] which is usually processed into fish meal.

The fish in this area are heavy feeders except during short periods of spawning, and consequently they are of a good size. Spanish mackerel is generally large (35 to 45 cm) although there is a population in the 25 to 35 cm range. Horse mackerel varies from 15 to 45 cm with the largest proportion in the 30 to 45 cm group. In the family Carangidae, yellow horse mackerel are taken with Spanish mackerel, horse mackerel and Sparidae. Sparidae are a large group of various sizes. In deeper water they are small (25 to 30 cm) while in shallow water they are larger (35 to 60 cm). In this group are found large-eyed dentex (*Dentex macrophthalmus*), bronze bream (*Pagellus acarne*), *Dentex marocanus*, *Pagrus ehrenbergi* and such as those belonging to the Sciaenid, Serranid and Trichiurid families. In the fishing grounds of Angola large hake (50 to 75 cm) (*Merluccius capensis*) make up about 80 per cent of the catch.

Climatic conditions

Sunny weather prevails in the Mauritanian area; daytime temperatures are from 18° to 25°C (64° to 77°F) in the north to 28° to 35°C (82° to 95°F) in the south. The difference in day to night temperatures varies only 2 to 5 degC (4 to 9 degF). The sea-water temperature at the surface varies from 17° to 26°C (63° to 79°F) in the north to 26° to 29°C (79° to 84°F) in the south.

In the Angola area August temperatures were 13° to 17°C (55° to 62°F) with sea-water temperatures of 14° to 15°C (57° to 59°F). The number of days of overcast and fog were greater here.

Factors influencing the quality of fish from the time they are landed on deck until freezing

The size of haul of the Polish bottom trawlers varies from 0.1 to 20 t, with 75 per cent taken in daylight hauls. The haul size at night is small. The species variation is high. The deterioration on deck is extremely high in the tropics and subtropics when compared to moderate and subarctic regions. Factors influencing this deterioration are:

(1) Large variations in the size of hauls necessitate delay in freezing when the catching rate exceeds freezing capacity.

(2) During large hauls there is much damage to fish through crushing in the net and considerable delay in clearing the fish from the net and getting it below deck.

(3) The strong rays of the sun heat the fish quickly and greatly accelerate *post-mortem* changes.

Influence of the size of the fish bulk per haul on the quality of wet fish

Such influence is more obvious on the earlier vessels where preservation of wet fish is more limited.

There is a lack of towing control which results as above in excessive loads in the cod end and a delay in handling fish to the freezers. As there is little hope of regulating catch size as well as a vertical migration of fish at night the catch sizes will remain variable. Where the catch size is 3 to 4 t, aboard the new trawlers there is no problem in handling fish to the freezers. As 30 per cent of the catch is non-food species the time to the freezer does not exceed 3 h. Quality does not deteriorate and the discharge of the cod end does not take more than 10 to 15 min. The fish are taken directly below deck, iced and frozen.

When the cod end contains 10 to 15 t there is excessive crushing and time delay. Each split takes 1 to 1½ h. One species damages the other. The smaller fish are subjected to such pressure and handling that they do not undergo *rigor*. The amount of damage varies from mechanical to damage by crushing, not only by volume in the cod end but by species variation as well as size variation and the duration of handling.

Numerous observations can only give some guidance to fish deterioration. Small sardines in the presence of large Sparidae in large hauls are damaged to the point where they are unfit. Spanish mackerel damage fluctuates from 10 to 20 per cent in hauls above 10 t, but 5 to 10 per cent when free of the family Sparidae. In Cape hake and Sparidae it amounted to only 3 to 5 per cent.

Changes in quality in fish kept on the open deck

In large hauls fish must be kept on the open deck for 2 to 3 h or longer. This is the time required for emptying the cod end, sorting and shooting the gear as well as protecting the fish fit for freezing.

The investigations on *post-mortem* changes were carried out in the region of Mauritania at air temperature 22°C (72°F), and sea-water temperature 20°C (68°F); in the region of Senegal at air temperature 30°C (86°F) and sea-water temperature 28°C (82°F); in the region of Angola at air temperature 14°C (57°F) and sea-water temperature 14°C (57°F).

Fig 1. Emptying of cod-end. Pressure areas indicated by arrows

Fig 2. One of the next steps in emptying the cod-end

Process of fish heating on deck. During long delays the piles of fish remain undisturbed. The observations made in such cases are given in table 1.

TABLE 1. COURSE OF FISH HEATING ON DECK

Time of measuring	*Temperature*			
	Fish from the surface layer of the pile		*Fish from the centre of the pile*	
	°C	°F	°C	°F
At the moment of discharge on deck	15	59	15	59
After 1 h	29	84.2	18	64.4
After 2 h	33	91.4	20	68
At the moment of discharge on deck	28	82.4	28	82.4
After 1 h	35	95	30	86
After 2 h	38	100.4	31	87.8

The closer to the deck the higher the temperature increase. The heating on a wooden deck was slower than on steel and not as uniform. After 2 h there was a slight decrease in temperature in both cases. No such phenomena was noted in Angola, when the air temperature was 13° to 17°C (55° to 63°F) and the sun somewhat obscured.

The course of quality changes. Observations were made on Spanish and horse mackerel and Cape hake from Angola. The fish for investigation were taken from hauls of small or average size and were therefore for the most part alive.

Changes in quality in the outer layers of fish in Mauritania–Senegal region. The outer fish are dried and mis-shapen by the sun. Strong heating causes a high flow of blood fluid from the tissue on cutting. In Spanish mackerel at temperatures above 28°C (82°F) it increases excessively with time and temperature increase.

This same increase above 30°C (86°F) causes acceleration of autolytic changes widened by discolouration of the belly flaps in 2 h and easy rupturing of the muscle tissue.

The odour characteristics were not objectionable during this period. The fish samples were frozen in plate freezers, stored at −25°C (−13°F) and examined showing:

(1) obvious corrugation of the skin on one side;
(2) autolytic discolouration of fish kept for 1 h on deck, which was not evident before freezing;
(3) bleaching of meat tissue, similar to a short hot-water blanch;
(4) slight deterioration of flesh consistency;
(5) a decreased amount of drip during thawing from fish at the edge and centre of the pile from 0.1 to 0.6 per cent. The flesh texture of the low drip product was quite tough.

Changes in quality of fish from the middle of the pile. Spanish mackerel and horse mackerel with temperatures of 20° and 27°C (68° and 81°F) were investigated. The results from these observations were based on piles of approximately 100 kg as it was difficult to work with large piles. The results are therefore only a guide as large piles also suffer from heating in the pile and excessive pressure as well as longer storage on deck. While the quality of the fish from outside to inside varied under different initial temperatures, the hot sun has a levelling effect on these temperatures. The outer layer does protect the inner layer to some degree as illustrated in table 1. It is noted that heating is not indicated in the smaller piles.

Table 2 records the time for organolytic changes to take place. In Spanish mackerel the first changes noted are autolytic and result in soft flesh. These changes take place at 27°C (81°F) on the open deck in 2 to 3 h and continue during freezing. The same reaction is noted with fish at the lower temperature range of 20°C (68°F) stored for 3 to 5 h.

Large horse mackerel shows more resistance to temperature at every stage.

It is interesting to note the lack of correlation between flesh consistency and odour. Spanish mackerel stored up to 6 h on deck at 27°C (80°F) while it was obviously soft and unacceptable showed no objectionable odour.

On the contrary, however, bottom fish and sometimes horse mackerel which had been kept on deck several hours at 30°C (86°F) showed a firm flesh but an objectionable odour.

Fig 3. Showing corrugated skin of mackerel kept exposed to the sun for 1 h (a). Compare with fish taken from inside the pile (b).

Fig 4. Cross cut of mackerel flesh; (a) exposed to the sun; (b) unexposed

Cape hake in temperatures 14°C (57°F) in Angola region. Cape hake from South Africa is much firmer in fresh state than Senegal hake (*Merluccius senegalensis*). It resembles Baltic cod during the summer. Table 2 illustrates the quality change in Cape hake at 14°C (57°F) after 2 to 3 h. While it is still in *rigor* it shows discolouration of the belly flaps. Softening of the flesh takes place

TABLE 2. TIME (IN HOURS) OF APPEARANCE OF POST-MORTEM CHANGES IN FISH FROM THE MIDDLE LAYERS OF THE PILE

Description of changes	*Spanish mackerel* $t = 20°C$	$t = 27°C$	*Horse mackerel* $t = 20°C$	*Cape hake* $t = 14°C$
Rigor mortis onset	0.25–0.50	0.15–0.30	1–1.5	2–2.5
Rigor mortis resolution	3–4	2.5–3	4–5	4.5–5
Incipient discolouration of belly flaps	6–8	3–4	8–10	2–3
Consistency of flesh:				
loss of firmness	3–4	2.5–3	5–6	5–6
soft/not acceptable	6–8	4–5	8–10	10–12
very soft/spoiled	10–12	6	—	After 20
Odour of flesh:				
less fresh—neutral	2	2	4	6
slight stale/limit of acceptance	10	5	12	12

soon after *rigor*. These observations were made during the best conditions for that area, namely the normal winter season.

Influence of pre-chilling of wet fish on its quality in the frozen state

It is obvious in tropical climates that to obtain frozen fish of good quality all the fish must be frozen within 2 to 3 h from the time it lands on deck or it must be pre-chilled prior to freezing. Since it is impossible to process all fish quickly there is a wider acceptance of the latter technique on the newer vessels.

The Polish trawlers use two methods: by flake ice from sea-water and by RSW in special tanks.

Since it is difficult to ice fish well in the tropics without much use of hand labour, the method of pre-chilling in RSW has many advantages.

Experiments were carried out using tanks of 0.5 m^3 capacity. Cooled and uncooled water was used. One aim was to get some data on the transfer of fish via the floating bag method (Birkhoff's method) for subtropical and tropical areas. Secondly, the aim was to establish the conditions and time necessary for pre-chilling of the main commercial species. Spanish mackerel and Cape hake were used. Organoleptic assessment was carried out *in situ* prior to freezing for later evaluation.

Quality changes in Spanish mackerel and Cape hake in cooled and uncooled sea-water. The lots were divided into two parts; one was placed in sea-water at 0°C (32°F) and the other in non-cooled sea-water. The water-to-fish ratio was 1 : 1. Samples were taken from the cooled tanks at 6-h intervals, from the non-cooled tanks at 3-h intervals. The sample was continued until the fish was obviously spoiled. The samples were frozen and held for five months at −25°C (13°F).

The *post-mortem* changes are illustrated in table 3. Minor changes were not noted that distinguish this fish from iced fish:

(1) bleaching of the skin, gills and sometimes the eyes which shows up after 24 h in cooled water, and 6 to 12 h in uncooled water;
(2) along with the same bleaching is an increase of translucent slime;
(3) a slight swelling of the fish due to water absorption which makes the determination of *rigor* changes difficult to the point of indicating a prolonged false *rigor*.

Examination of the thawed samples indicated that deterioration continued during the first stages of freezing. As illustrated in table 3 it can be assumed that Spanish mackerel and Cape hake can be kept in RSW at temperatures near 0°C (32°F) for at least 24 h and for at least 5 to 6 h in uncooled water at temperatures of 14° to 20°C (57° to 68°F) with little loss in quality. On examination of fish after thawing it is indicated that to obtain a good quality product these times must be halved. As it is almost impossible in practice to reach temperatures of 0°C (32°F) the time should be shortened to 8 to 10 h.

Miscellaneous investigations

The following observations were made along with the organoleptic ones:

(1) Determination of free drip at room temperature.
(2) Determination of total solids of the drip.
(3) Determination of trimethylamine (TMA) and total volatile bases (TVB) in the flesh.

The condensed results are shown in table 4 comparing them to fresh fish. The TMA and TVB results did not correlate with actual quality. They frequently showed lower values after storage.

TABLE 3. TIME (IN HOURS) OF APPEARANCE OF POST-MORTEM CHANGES IN SPANISH MACKEREL AND CAPE HAKE KEPT IN SEA-WATER

Description of changes	*Cooled sea-water*		*Non-cooled sea-water*	
	Spanish mackerel $t = \pm 0.2°C$	*Cape hake* $t = 3.5–0.5°C$	*Spanish mackerel* $t = 20°C$	*Cape hake* $t = 14°C$
Rigor mortis onset	0.5–1	6–7	0.25–0.50	1.5–2
Rigor mortis resolution	60–72	40–42	5–6	9–10
Incipient discolouration of belly flaps	36	50	7–9	5–6
Consistency of flesh:				
loss of firmness	48	24	6–9	6–7
soft/not acceptable	72	72	9–12	12–15
very soft/spoiled	After 120	100	18–20	24
Odour of flesh:				
less fresh—neutral	48–60	36	3–4	5–6
slight stale/limit of acceptance	144	127	12	12

TABLE 4. PERCENTAGE RATE OF FREE DRIP AND THE CONTENTS OF TMA AND TVB ESTABLISHED REPEATEDLY WITHIN THE TIME GIVEN BELOW

Fish species and storage	*Storage*		*Drip* (%)	*Dry substance in the drip* (%)	*mg N/100 g meat*	
	Temperature (°C)	*Time* (h)			*TMA*	*TVB*
Spanish mackerel:						
frozen immediately upon discharge on deck	—	1	0.3	6.9–9.7	3.4–4.5	21.3
taken from the outer layer of the pile	28–33	4	0.12–0.13	14.4	4.5–5.6	19.0–22.4
taken from the middle part of the pile	20	12	0.6–0.7	9.9–13.0	4.5–9.6	22.4–27.4
taken from non-cooled water	20	24	0.6–1.6	6.8–8.1	4.5–11.8	21.3–29.1
taken from cooled water	0	144	1.4–2.7	5.9–7.4	3.9–7.3	17.9–22.9
Cape hake:						
frozen immediately upon discharge on deck	—	1	2.0	4.7	5.6	16.8
taken from the deck	14	24	1.2–1.9	4.6–5.4	4.5–5.6	13.4–15.7
from non-cooled sea-water	14	24	1.6–3.8	4.6–5.3	4.5–8.4	14.5–17.9
from cooled water	−0.2/+3.5	144	1.5–4.8	4.2–5.0	3.4–6.7	12.3–17.4

CONDITIONS NECESSARY TO MAINTAIN GOOD QUALITY OF FROZEN FISH ABOARD VESSELS OPERATING IN TROPICAL AND SUBTROPICAL AREAS

These requirements for Polish vessels in the West Africa area could be summarized as follows:

(1) To prevent bruising by crushing during the discharge of fish on deck there should be some control used in the filling of the cod end and also some improvements for emptying it.

(2) The fish should be discharged from the net directly below deck and immediately chilled. This requires special installations for chilling.

(3) The fish should be chilled in RSW at 0°C (32°F); however, temperatures of 3° to 5°C (37° to 41°F) are considered adequate.

(4) The time that the fish should be held in the tanks should be kept to a minimum, and should be no more than 12 h.

(5) When holding fish on deck is unavoidable, it should be thoroughly graded as to quality before freezing, discarding the lower quality fish.

In order to satisfy these requirements, many technical problems will have to be solved with both fishing gear and equipment aboard the vessel. The RSW tanks must be designed for easy emptying and cleaning. The improvements for a fast discharge of the cod end in large hauls must be modelled after the trawlers of the B-18 type. In the U.S.S.R. it is recommended that the cod end be opened down the side for discharge. The fish are then washed into the tanks with water jets.

In conclusion, it can be said that vessels of the B-18 type that employed the use of RSW delivered fish with a better uniform quality than trawlers with no such installations.

References

ANON. 1964 Sbornik rabot po technologii rybnych produktow, Kaliningrad.

OECD 1965 *Fish Handling and Preservation*, OECD, Paris.

DISCUSSION

Subba Rao (FAO): In the countries of South-east Asia, fish is an important item in human diet and surveys conducted in some of the countries (e.g. Burma) reveal that up to 30 per cent of the family food budget is spent on fishery products. The general trend during the last few years has been towards increased consumption of fresh and frozen fish in preference to the traditional salted and dried products. In some countries, notably India, the quantities of fish available for salting and drying have actually decreased due to increased facilities available for icing, freezing and cold storage. While there was general consumer preference for fresh fish, production and consumption of frozen fish in the South-east Asian countries is increasing. In Thailand, the Fish Marketing and Cold Storage Organizations operate a plant for freezing seasonal gluts of mackerel (*Rastrelliger* sp.) and other fish, which are then marketed during the lean season in order to regulate prices. In Ceylon, production and consumption of frozen fish has increased considerably and the consumers, particularly in the urban areas, prefer frozen fish to dried fish. In general, it may be stated, that subject to certain economic considerations, there is no problem concerning consumer acceptance of frozen fish, provided the quality is good. In some countries, particularly India, Pakistan and Thailand, a sizeable export-oriented industry in frozen crustaceans has developed.

The current methods used for freezing fish include plate freezing and freezing in air, but brine freezing is seldom practised. Plate freezing is generally satisfactory, but the temperatures used for air freezing are too high. The same room is frequently used, for both air freezing and frozen storage, at temperatures of −10° to −20°C (14° to −4°F). In most cases, the air is not circulated. Very few installations have equipment for "quick" freezing in air at −30°C (−22°F) or lower. The raw material used for freezing is usually one to seven days old in ice. Periodic glazing of the frozen product is generally practised.

Under these conditions the following general observations can be made, although the quality of the frozen fish varies considerably:

(1) Freezing and subsequent cold storage at temperatures (about −18°C, 0°F) which are higher than those normally considered suitable for quick freezing, does not appear to seriously damage the muscle texture of the tropical fish, particularly fishes of the mackerel, tuna and allied group, immediately after the freezing, but the texture of the meat toughens fairly rapidly within a few weeks in frozen storage.

(2) The fat content of the muscle appears to have considerable influence on the extent of damage to its texture by freezing and cold storage. It may be noted that only a few of the commercially-important species of tropical fish may be considered as "lean", like, for example, the cod and haddock of the colder waters. The high sensitivity of the cod muscle to different rates of freezing is well known and observations show that slow freezing of actomyosin from cod and haddock render the muscle protein almost completely inextractable by dilute salt solutions. However, we have very little information as to whether it is the fat content of topical fish that provides their resistance to textural damage at the comparatively high freezing temperatures.

The growth of the fish freezing industry in South-east Asia is hampered by a number of problems:

(a) Though the use of ice in fresh fish handling is widespread, ice prices are generally high. They vary from U.S. $5 to $25 or more per tone and in most countries they average around U.S. $10 per ton. The consumption of ice, including icing on board, re-icing on shore during transport and at wholesale and retail markets, varies according to the distance to the consumer centres, but surveys have indicated that ice consumption is about twice the weight of fish for short distances and three to three and a half times the weight of fish for distances of 1,000 miles or more, when insulated, but not refrigerated, transport is used. This would add U.S. $20 to $35 to the price of each tone of fresh fish handled. On the other hand, charges for freezing fish in most countries of South-east Asia vary from U.S. $14 to $25 per tone of fish. Actually, in urban areas of Ceylon, fish frozen and marketed within a few days is competitive in price with iced fish and is preferred by the consumers. In view of the high price of ice, a survey is needed on the economics of freezing fish and distributing it within a short period.

(b) Since most of the commercially important species of fish in South-east Asian waters are not "lean" like the principal commercial species of the North Atlantic, a

systematic study should be made, to determine the optimum conditions of freezing and cold storage temperatures, with particular reference to the economics of the process, and to transportation and marketing costs.

(c) Frozen fish is generally sold in the markets in the same way as fresh fish and no attempt is made to keep it frozen once it is removed from the cold storage. Very little information is available on the keeping quality of the fish from tropical waters under these conditions. In most cases, fish will be disposed of during the day on which it is removed from the cold store. Nevertheless, information on the keeping quality of frozen and thawed fish held either at room temperature or in ice would be of great value to the industry.

(d) Elasmobranch fishes generally bring good prices and frozen shark steaks are popular items in some countries, particularly Ceylon. One of the problems in the storage of the frozen sharks is the development of ammonia, since the freezing process does not deactivate the urease.

(e) Use of frozen raw material for canning, for manufacture of comminute fish and starch products, fermented fish and fish pastes, needs to be studied. Information is also lacking, concerning the viability in frozen fish, of the enzymes responsible for texture and flavour of fermented products.

Watanabe (FAO): With regard to the effect of fresh fish quality on frozen product, I would like to mention the muddy taste problem with frozen fish from Lake Kariba. Fish are mostly gill-netted and arrive at fish freezing plant in Kariba 2 to 10 h after being taken out of water and the quality is rather poor. They are frozen by air blast freezer in 12 h down to −18°C (0°F) and sent to main consumer centres. The products have been readily accepted by the local population and demand is still increasing despite the poor quality. The local population is not concerned about such product faults as tough texture and rancidity, but we have heard many complaints on muddy taste. This defect, we found, occurs mainly in specimens of *Tilapia mossambica* of a darker colour. The muddy taste is more pronounced in the oily tissue such as belly flaps. I was informed by a biologist that this species is a bottom feeder and this may account for the muddy taste. I would like to have any suggestions on methods for controlling this problem. The solution would be important, not only for Lake Kariba, but also for other large man-made lakes in Africa.

Jones (U.K.): Results on hake freezing in the S.W. Atlantic in the recent British exercises are in general agreement with the Polish data.

With regard to the muddy flavours encountered in some frozen tropical fresh-water species mentioned by Watanabe, recent work at Tropical Products Institute shows that the condition is readily eliminated by leaching by ice melt water (or a chilled water wash) prior to freezing or subsequent to thawing. It is possible to arrange the leaching regime to remove detectable off-flavour without removing all desirable sweet flavour. The off-flavour appears to be related, at least in part, to the presence of a thioether of relatively high molecular weight.

Evaluation of Techniques and Equipment for Thawing Frozen Fish

by J. H. Merritt

Evaluation of techniques and equipment for thawing frozen fish

Thawing methods of current interest are described together with some discussion of their advantages and disadvantages: air blast, water, heated plates, dielectric and electric resistance. Whole fish and fillets are considered but emphasis is placed on industrial thawers for blocks of whole fish, particularly of the sort frozen at sea, typically 50 × 100 × 10 cm thick and about 40 kg in weight.

Evaluation des techniques et du materiel pour la décongélation du poisson congelé

La communication décrit les méthodes de décongélation présentant actuellement un intérêt et examine leurs avantages et leurs inconvénients: courant d'air forcé, eau, plaques chauffantes, méthode diélectrique et résistance électrique. L'étude porte sur les poissons entiers et sur les filets, mais s'attache particulièrement aux décongélateurs industriels pouvant recevoir des blocs de poissons entiers, et plus particulièrement les blocs congelés en mer, qui ont pour dimensions courantes 50 × 100 × 10 cm et un poids d'environ 40 kg.

Evaluación de las técnicas y equipo de descongelación del pescado congelado

Se describen métodos de descongelación de interés actual junto con un examen de sus ventajas e inconvenientes: por ventilación, agua, placas térmicas, resistencia dieléctrica y eléctrica. Se estudian el pescado entero y los filetes, pero se dedica atención principalmente a las descongeladoras industriales para bloques de pescado entero, especialmente el congelado en el mar, que suelen tener un tamaño de 50 × 100 × 10 cm y unos 40 kg de peso.

WITH few exceptions, frozen foods must be thawed before they are served and eaten. In some cases this imposes little difficulty; frozen vegetables are often heated quickly by placing them in boiling water, sometimes it is convenient to thaw poultry at room conditions before it is prepared for cooking, frozen fish fingers can be placed directly under the grill without preliminary thawing. The production of frozen foods prepared for combined thawing and cooking is increasing.

In many cases, however, the need for thawing causes inconvenience. For low cost handling, packing, freezing and transport it is often essential to have the product in bulk form which can make thawing difficult. Thus a caterer may require special facilities for thawing large packs of frozen food on short demand and thawing on an industrial scale is required for the processing of frozen fish landed by fishing vessels.

Although large, sophisticated factory ships are capable of complete processing of the catch and might use methods of preservation other than freezing, the trend toward freezing at sea with limited processing on board no doubt will continue for at least 10 years. Also it will be feasible in some instances to freeze fresh fish on shore after little or no processing when they are in good supply and cold store them for later use in production. There will be continuing interest, therefore, in the development of plant for thawing a wide range of species on a large scale, especially for the thawing of whole fish such as cod (*Gadus morhua*) and herring (*Clupea harengus*), in compact blocks 4 to 10 cm thick, with a weight of about 0.8 that of a solid block of corresponding size.

Methods of thawing

Thawers can be divided into two broad classes: those which depend only on the conduction of heat through the thawing material and those which do not. The methods of most interest at present are thawing in air, thawing in water and thawing between heated plates, which fall into the former class, and dielectric thawing and electric resistance thawing which fall into the latter class. There are other methods, such as infra-red and microwave heating, but they are not of interest for thawing on a large scale.

The rate of heat input required to thaw 1 t of fish per hour is approximately 85 kW.

THAWING IN AIR

Natural convection

It is sometimes convenient to thaw at room conditions, or out of doors if conditions are suitable. There is little deterioration in the quality of whole cod in 10 cm blocks when thawed at an air temperature of about 15°C (59°F) although the thawing time is approximately 20 h (Anon., 1957). Temperatures above 18°C (64°F) should not be used. A lot of space and labour is required for thawing on a large scale by this method and the introduction of humidification to prevent some drying of the fish is difficult.

Air-blast

Increased air velocity will reduce thawing time. The resistance to the flow of heat at the boundary near the fish diminishes with increased velocity so that at 6 m/s there is little resistance, the surface temperature practically equals the air temperature and the rate of thawing is mainly dependent on the resistance of the fish itself. Thus in modern air-blast thawers for blocks of cod, herrings and other fish with recirculation of humid air at 20°C (68°F), the maximum temperature that should be employed, the 10-cm blocks of cod will require about 5 h before they can be filleted. The fish can be separated easily after about 3 h which will reduce the thawing time to about 4½ h and give more even thawing. The rate of heat input is very low during the later stage of thawing

and, since there invariably will be differences in thawing rate between fish in a block, the time in the thawer must be ample if filleting is to be carried out immediately. Incompletely-thawed whole fish can create difficulties in filleting and give reduced yield depending on the amount and distribution of ice in the flesh. It has been common practice, however, to have a delay of more than 12 h at ambient conditions before processing during which some thawing and tempering of incompletely-thawed fish can take place. In a typical case, the fish are placed in boxes with a little ice sprinkled on top after an initial period of only 4 h in the thawer.

Complete humidfication of the air is necessary in order to prevent drying of the fish and to achieve ideal conditions for heat transfer (Reay *et al.*, 1950; Merritt and Banks, 1964). Weight losses in the fish normally do not exceed 1 per cent. In some designs water is sprayed directly on to the fish and in others the air is humidified by sprays near the heaters. It would be possible to supply the heat to the spray water instead of directly to the air.

The problem of cleaning is greater with the air-blast thawer than with most other types. Ease of cleaning should be considered in the design.

Continuous

Continuous air-blast thawers of two types have been built: cross flow and parallel flow.

In the cross flow design the direction of air flow is across the conveyor(s) at right angles. Typically there are five conveyors, one above the other. The fish travels horizontally along the top conveyor until, when it reaches the end, it falls to the conveyor below which is travelling in the opposite direction and so on. If there has been sufficient thawing, blocks of fish will break up on dropping from one conveyor to the next. In order to achieve high velocity, fan capacity has been high with this arrangement so that fan power is more than 30 kW for a unit designed for an output of 1 t/h with 10-cm blocks of whole fish (Connell, 1965). Thus a large portion of the heat for thawing is fan heat. In fact there is a tendency to overheat the air, especially at part load.

In the parallel flow thawer the air travels in the same direction as the conveyor. With humid air, most of the heat transfer to the fish takes place by condensation of water vapour and an air temperature drop of 3°C (5°F) can be tolerated. The fan capacity is relatively low, therefore, fan power is about 7.5 kW for the 1 t/h unit and the face area of the heater and humidifier is smaller. Evidently there are only two installations of this type. In one the conveyor is in a single line occupying a greater floor area than a cross flow thawer. In the other the conveyor is divided into three sections, one above the other.

The cost of continuous air-blast thawers rated at 1 t/h has been in the region £15,000 to £20,000 (U.S. $36,000 to $48,000) in the United Kingdom. More than half the cost has been for conveyors.

Batch

The Torry kiln for the smoking of fish has been the basis of a batch air-blast thawer. The largest model has five compartments, each holding 1 t of 10-cm blocks of whole fish on two trolleys with suitably-spaced shelves, giving an output of about 1 t/h. Air flow is in series, through the five compartments in a line. Periodic reversal of air flow can be employed to even out differences between compartments. Also the thawer can be used on a semi-continuous basis by inserting and withdrawing trolleys at intervals of 1 h. More labour for loading and unloading is required than for continuous thawers but the batch thawer is simple and compact. The 20-kW fan, heaters and humidifier are located above the fish compartments (Wignall, 1967).

Several units have been installed at an initial cost of roughly £6,000 (U.S. $14,400) each.

Batch thawers with small fans giving moderate velocities, in which blocks of fish are placed on racks or shelves, have been used for thawing over periods of up to 10 h. In some cases whole fish is thawed overnight in preparation for processing during the normal working day.

WATER THAWING

Immersion

The thawing of blocks of whole fish in water has been shown to give good results but has been used to only a limited extent for thawing on a large scale (Magnusson, 1955; Magnusson and Hartshorne, 1952; Merritt and Banks, 1964). Recent work with blocks of whole cod and herrings which included tests with a pilot scale thawer in a factory has shown that the thawed product can be as high in overall quality and suitability for processing as the fish from an air-blast thawer and that waterlogging followed by increased drip loss after thawing can be within acceptable limits in practice (Hewitt, 1967).

Pump capacities for water thawers need not be great because the water velocity required for good heat transfer is 0.5 cm/s (MacCallum and Ellis, 1964a), giving thawing rates equal to those for air-blast. It probably will be necessary, however, to use somewhat higher velocities, perhaps 2 cm/s or more, in order to give a good degree of mixing of the water, preventing stratification and to provide reasonably quick response to the heater, particularly for warm up with initially cold water. Too high velocities will induce turbulence, causing foaming at the surface of the water and possibly lead to waterlogging. Temperature should not exceed 18°C (64°F).

The water can be recirculated in order to conserve heat. Based on experience to date it would have to be changed once or twice per 24 h, perhaps with a small fraction of continuous waste and make up in order to limit the degree of contamination of the water. Cleaning of a properly designed plant would present no difficulties.

Even a rough estimate of the cost of an industrial water thawer is difficult because there are no established designs. If the occupied floor area is to be kept low, design will be more difficult. Nevertheless, based on the results of pilot scale trials, continuous water thawers may give satisfactory results at costs lower than any existing method.

Spray

A large thawer in which heated water is sprayed directly on the fish has come into use recently (Anon., 1967). The blocks of fish travel on a conveyor which is made up of a series of open mesh wire baskets in a housing ventilated

by a small fan. The water is recirculated, except for some make up, through a special filter and cleaner section. The thawing time is claimed to be at least as short as in air-blast thawing. Hygienic conditions are maintained in the thawer because of the washing action of the sprays of clean water.

The cost has been estimated at £17,000 (U.S. $40,800) for a unit with an output of 1 t/h, based on a thawing time of 5 h with the 10-cm blocks of whole fish. A large portion of the cost is in the conveyor system (personal communication, 1967).

Water sprays have also been used in the thawing of blocks of sprats (*Clupea sprattus*), herrings and other small fish. The thawer can be arranged so that the fish fall away from the block as thawing proceeds and are automatically drained and conveyed from the thawer (Karsti, 1965).

THAWING BETWEEN HEATED PLATES

Schemes for the thawing of fish between heated metal plates have been devised (Anon., 1967). The thawer is similar to a plate freezer except that warm fluid, normally at 20°C (68°F), is circulated through the plates. The produce is held in contact with the plates throughout the thawing period which is about 8 h for complete thawing of the 10-cm block of whole fish.

It is claimed that, with 10-cm blocks of whole fish, thawing is more even than in air-blast thawing, with the result that the fish can be filleted sooner, typically 7 h after an initial period of 4 h in the thawer as opposed to 12 h in air-blast thawing. Excluding the heat for thawing, little power is required. The plant is compact and robust. Cleaning of the plates, framework, etc., is necessary but presents no difficulty.

The estimated cost of a unit with an output of 1 t/h with 10-cm blocks of whole fish, based on a thawing time of 5 h, is £10,000 (U.S. $24,000).

DIELECTRIC THAWING

In dielectric thawing the frozen material is placed in a high-frequency electrical field between two flat metal plates (Jason and Sanders, 1962). Alternating voltage is applied to the plates, typically 5,000 V and 40 MHz, resulting in movement and hence production of heat in the electrically charged particles in the food. The plates are fed from a generator and suitably shielded to confine the field. Unless the food is homogeneous and regular in shape there will be a tendency for uneven heating so that parts of the material will be cooked while other parts remain frozen. This can be minimized in blocks of fish by continuously conveying them through the field and restricting the power density according to the degree of thawing that has taken place. Thus a typical industrial thawer for blocks of fish includes a conveyor belt and six generators, each with a rating of 20 kW, giving a nominal output of 1 t/h with 10 cm blocks of whole cod.

Because a conveyor and several generators are required the method is not attractive for small installations but it is versatile. Fillets and smoked fish can be thawed dielectrically. Thawing is very rapid so that the total length of conveyor has been much shorter than that for continuous air-blast thawers. The thawing time for blocks of white fish is about 80 min and for blocks of herring about 20 min. Blocks of herrings and fillets can be placed directly on the conveyor. Blocks of whole white fish and single fish are placed in plastic trays filled with water in order to give more uniform thawing. There is little effort required for cleaning as the trays and conveyor are easily cleaned.

By good control of thawing conditions, especially at reduced output, overheating in 10-cm blocks of whole cod can be confined to tails and bellyflaps which are trimmed off on filleting (MacCallum and Ellis, 1964b). It has been the practice in the United Kingdom, however, to stop short of complete thawing which avoids the risk of overheating. As in air-blast thawing, there is a delay before filleting.

The cost of dielectric thawers with a nominal rating of 1 t/h has been in the region of £24,000 (U.S. $57,600).

Dielectric and water

The dielectric thawer has a thermal efficiency of about 70 per cent. The waste heat is absorbed by cooling water for the generators. It has been suggested that this heated water be used for thawing either before or after the dielectric thawer, a hybrid system, in order to increase output and thermal efficiency and reduce the risk of overheating.

Since heat conduction is rapid during the early stages, the 10-cm block of whole fish can be 30 per cent thawed in less than 30 min in water at 15°C (59°F). Thus the output of a dielectric thawer with a nominal rating of 1 t/h could be substantially increased by the introduction of an initial water stage.

Water thawing after an initial stage of dielectric thawing has also been proposed. About 70 per cent of the heat is added in the dielectric thawer over a period of 30 min, after which the fish are easily separated, followed by thawing in water at 15°C (59°F) for up to 80 min depending on the size of fish. The fish are completely thawed, ready for filleting, with little risk of cooking (Jason and Sanders, 1967).

ELECTRIC RESISTANCE THAWING

Fish can be heated by placing it between two electrodes and applying a low voltage so that a current flows through. Like dielectric heating, it is difficult to achieve even heating unless the item is homogeneous and regular in shape. Good results can be obtained easily with blocks of herrings and fillets. A small unit with one pair of electrodes suitable for caterers has been developed (Jason, 1965).

It is convenient to partially heat the fish by a heat conduction method such as immersion in circulating tap water because the electrical resistance of frozen fish decreases sharply on increase in temperature and thawing by heat conduction is rapid during the early stage. Usually the times of water immersion and electric heating should be roughly equal. The total thawing time will be between 20 and 60 min depending on the type of block, at least twice as fast as thawing in air or water (Sanders, 1963).

There are no batch or continuous systems for thawing on an industrial scale although blocks of whole fish have been thawed with success in the laboratory. A compact batch thawer of this type has been proposed, with plates and blocks of fish arranged in layers one above the other in the same way as a horizontal plate freezer. The plates are heated electrically or by passing warm fluid through them during the early stage of thawing when heat conduction is employed and act as electrodes during the stage of electric resistance thawing.

It is estimated that the cost would be roughly the same as the cost of a dielectric thawer.

CHOICE OF METHOD

Many factors must be considered when choosing between the various methods. The choice will depend largely on the type of produce and the form in which it was frozen. In some cases it has been difficult to provide sufficient shielding in the dielectric thawer to satisfy the authorities responsible for radio broadcasting (Bengtsson, 1965). The air-blast thawer might be at a disadvantage in the amount of cleaning required to keep bacteria counts within statutory limits (Shewan, 1967). There is a lack of published data on the bacteriological aspects.

Whole fish

All the main methods described above can produce satisfactory results with blocks of whole fish in that there need be no appreciable deterioration in eating quality. Both heat conduction and electric methods fail to give precisely uniform heating with large fish, however, which imposes some difficulties if the fish are to be processed immediately after leaving the thawer. The electric methods give more uniform thawing with compact blocks of small fish.

Differences in the total costs of thawing in continuous air-blast and dielectric thawers have been small and the cost with the new water spray method probably will be about the same. The cost of thawing the 10-cm blocks of whole fish has been in the range £4 to £6 (U.S. $10 to $15) per ton. Only the continuous water immersion thawer, which has not been developed to the industrial level in the United Kingdom seems to offer some hope of a substantial reduction in cost.

Continuous thawers would appear to have advantages over batch thawers for blocks of whole fish in a production line. In an ideal arrangement it might be feasible to place the blocks on a conveyor in the cold store for direct passage through the thawer. In many cases, however, the cold store is remote from the thawing plant which must remain in operation for more than 20 h per day to supply thawed fish for processing over a normal working day of 8 h. Thus the practice of incomplete thawing followed by a substantial delay before processing creates no great problems, although extra space and handling are required and there will be a slight deterioration in fish quality during the delay period. At present in the United Kingdom, therefore, batch air-blast thawers are in favour, principally because of simplicity, flexibility and low first cost. Apparently these advantages have not been completely offset by the higher labour requirements for operation and cleaning.

Little has been reported on the question of yield on filleting whole fish thawed by the various methods. There will be differences depending on the procedure and degree of thawing and whether machine or hand filleting is employed. There may be no differences, however, where a long delay is introduced before filleting. Also, apparently no assessment has been made of degree of susceptibility of the flesh in partially-thawed fish to textural damage on handling, although some workers suspect that damage can occur.

Fillets

For blocks of fillets, water thawing is unsuitable and block thickness probably should not exceed 5 cm for thawing in humid air blast and between heated plates. The electric methods give good results with blocks of fillets. Blocks up to 10 cm thick have been thawed successfully to the point of separation, with a small amount of ice remaining, in the dielectric thawer using only three generators.

Fillets, unsupported by the skeleton and unprotected by the skin of the fish, are more susceptible than whole fish to deterioration on thawing, particularly shrinkage, discolouration and dehydration. Pronounced thaw-*rigor* accompanied by shrinkage and loss of fluid sometimes can be produced when thawing is rapid, for example in single fillets thawed in air blast in 30 min (Jones, 1965). There has been no evidence of ill effects due to thaw-*rigor* in whole fish.

NOTE. This paper was prepared as part of the program of the Torry Research Station.

References

ANON. 1957 Report on an experiment into the freezing of fish at sea. White Fish Authority, London.

ANON. 1967 Fish thawer from Baader. *Wld Fishg*, **16**(1), 47.

BENGTSSON, N 1965 Electronic defrosting of frozen fish. In *Fish Handling and Preservation*, OECD, Paris, pp. 159–171.

CONNELL, J J 1965 Unpublished observations. Torry Research Station, Aberdeen.

HEWITT, M R 1967 Thawing of frozen fish in water. FAO Technical Conference on the Freezing and Irradiation of Fish, 4th–8th September, Madrid.

JACKSTONE FROSTER LTD. 1967 Personal communication.

JASON, A C 1965 Selection of thawing methods. In *Fish Handling and Preservation*, Paris, OECD, pp. 191–202.

JASON, A C and SANDERS, H R 1962 Dielectric thawing of fish. Parts I and II. *Fd Technol., Champaign*, **16**(6).

JASON, A C and SANDERS, H R 1967 Unpublished observations. Torry Research Station, Aberdeen.

JONES, N R Freezing fillets at sea. In *Fish Quality at Sea*, 1965 Grampian Press, London.

KARSTI, O Thawing frozen fish in moist air. In *Fish Handling* 1965 *and Preservation*, OECD, Paris, pp. 173–179.

MACCALLUM, W A and ELLIS, D G Water-thawing of frozen 1964a cod blocks. *J. Fish. Res. Bd Can.*, **21**(1).

MACCALLUM, W A and ELLIS, D G Temperatures and thaw- 1964b drip associated with electronic thawing of Newfoundland cod. *Ibid.*, **21**(4).

MAGNUSSON, H W Freezing fish at sea—New England. 1955 Studies of miscellaneous handling problems. *Comml Fish. Rev.*, **17**(7).

MAGNUSSON, H W and HARTSHORNE, J C Freezing fish at sea 1952 —New England. Freezing and thawing studies and suggestions for commercial equipment. *Ibid.*, **14**(12).

MERRITT, J H and BANKS, A Thawing blocks of frozen cod 1964 in air and in water. *Annex 1964–1 Bull. int. Inst. Refrig.*

NORDISCHER MASCHINENBAU RUD. Baader. Personal com- 1967 munication.

REAY, G A, BANKS, A and CUTTING, C L The freezing and 1950 cold storage of fish. *Food Investigation Leaflet*, No. 11, HMSO, London.

SANDERS, H R Electric resistance thawing of fish. *Torry* 1963 *Memoir*, No. 143, Torry Research Station, Aberdeen.

SHEWAN, J M Unpublished observations. Torry Research 1967 Station, Aberdeen.

WIGNALL, J *Ibid.* 1967

Thawing of Frozen Fish in Water

by M. R. Hewitt

Thawing of frozen fish in water

Blocks of sea-frozen whole cod (*Gadus morhua*) were thawed in humid air and in water at 15° to 21°C (59° to 70°F) in the laboratory to compare quality and weight gain. The quality of the fish after thawing was satisfactory with both methods and the yield on filleting was the same. In all cases the water thawed fish gained between 1 and 2 per cent in weight whereas there was no significant change in air-blast thawing. There was an appreciable difference in weight loss in the fillets stored in ice at chill temperatures, more or less corresponding to the difference in weight gain on thawing. Fillets from whole thawed fish lost 4½ per cent in 48 h whereas fillets from air thawed fish lost 2½ per cent.

Following these tests, a pilot scale continuous water thawer with a capacity of 0.25 t/h was constructed and a trial carried out in a commercial factory. With blocks of cod, 107 × 50 × 10 cm thick, a water temperature of 18°C (65°F) and a period of immersion of 4 h were employed. This gave fish approximately 70 per cent thawed which suited the factory processing arrangements where there was an overnight delay before filleting. The fillets compared favourably with fillets from fish thawed in a large air-blast thawer in the same factory and the yield was greater. The marked weight gain and subsequent loss in the fillets observed in the laboratory were not encountered.

Twenty blocks of whole herring (*Clupea harengus*) were thawed in the water thawer with good results.

The trial demonstrated that water thawing is a viable proposition. In many cases a water thawer with small circulating pump and compact heat exchanger would be cheaper than the air-blast or dielectric thawers currently in use.

Décongélation dans l'eau du poisson congelé

Des blocs de morue entière (*Gadus morhua*) congelés en mer ont été décongelés au laboratoire à l'air humide et dans l'eau à des températures comprises entre 15 et 21°C (59° et 70°F) en vue de comparer la qualité et les gains de poids. La qualité du poisson après décongélation était satisfaisante avec les deux méthodes et le rendement au filetage était le même. Dans tous les cas examinés, le poisson décongelé dans l'eau avait gagné de 1 à 2 pour cent en poids; par contre, aucun changement significatif n'a été observé après la décongélation dans un courant d'air. On a noté une différence appréciable de perte de poids pour les filets entreposés dans la glace à des températures de réfrigération, correspondant plus ou moins à la différence de gain de poids à la décongélation. Les filets découpés à partir de poisson décongelé entier avaient perdu 4,5 pour cent de poids en 48 heures, tandis que les filets obtenus à partir de poisson décongelé dans un courant d'air n'avaient perdu que 2,5 pour cent.

A la suite de ces essais, un décongélateur à courant d'eau à l'échelle pilote, ayant une capacité de ¼ de tonne/h, a été construit et un essai a été effectué dans une usine commerciale. Des blocs de morue (107 × 50 × 10 cm) ont été plongés dans l'eau à une température de 18°C (65°F) pendant 4 heures. Le résultat a été une décongélation à 70 pour cent environ, s'adaptant par conséquent au cycle de traitement de l'usine, qui comportait un délai d'une nuit avant le filetage. Les filets obtenus à partir de ces blocs supportaient favorablement la comparaison avec les filets découpés à partir de poisson décongelé dans un grand décongélateur à courant d'air utilisé dans la même usine et ont donné un meilleur rendement en poids. On n'a pas observé dans ce cas, comme pour les filets examinés au laboratoire, un gain marqué de poids suivi d'une perte après filetage.

Vingt blocs de hareng entier (*Clupea harengus*) ont été décongelés dans un décongélateur à eau avec de bons résultats.

Les essais ont démontré que la décongélation par eau est une solution viable. Dans un grand nombre de cas, un décongélateur à eau avec une petite pompe de circulation et un échangeur de chaleur de faible encombrement reviendrait meilleur marché que les décongélateurs à courant d'air ou diélectriques actuellement utilisés.

Descongelación en agua del pescado congelado

Se descongelaron en el laboratorio en aire húmedo y en agua entre 15° y 21°C (59° y 70°F), bloques de bacalao (*Gadus morhua*) entero congelado en el mar con objeto de comparar la ganancia en calidad y peso. La calidad del pescado después de descongelado fue satisfactoria con ambos métodos y el rendimiento al filetearse fue el mismo. En todos los casos el pescado descongelado en agua ganó entre 1 y 2 por ciento en peso mientras que no hubo cambios importantes al descongelarlo con chorro de aire. Hubo una apreciable diferencia en cuanto a pérdida de peso en los filetes almacenados en hielo a temperaturas frías, correspondiendo más o menos a la diferencia en peso ganada en la descongelación. Los filetes del pescado entero descongelado perdieron 4½ per ciento en 48 horas mientras que los filetes de pescado descongelado por aire perdieron 2½ por ciento.

Como resultado de estos ensayos, se construyó una descongeladora de agua corriente a escala experimental con una capacidad de ¼ de tonelada por hora y se realizó un ensayo en una fábrica comercial. Con bloques de bacalao de un tamaño de 107 × 50 × 10 centímetros se empleó una temperatura de agua de 18°C (65°F) y un período de inmersión de 4 horas. Esto dio un pescado descongelado aproximadamente en un 70 por ciento que se adecuaba a los métodos de elaboración en la fábrica en donde se dejaba transcurrir una noche antes del fileteado. Los filetes resultaban mejores que los de pescado descongelado en una gran descongeladora a chorro de aire existente en la misma fábrica y el rendimiento fue mayor. La sensible ganancia en peso y la consiguiente pérdida en los filetes que se observó en el laboratorio no se dieron en este caso.

Se descongelaron en la descongeladora de agua con buenos resultados 20 bloques de arenque entero (*Clupea harengus*).

El ensayo demostró que la descongelación en agua constituye un procedimiento viable. En muchos casos una descongeladora de agua con una pequeña bomba de circulación y un intercambiador térmico de reducido tamaño, sería más barata que las descongeladoras de chorro de aire o dieléctricas que se usan actualmente.

WEIGHT changes during humid air-blast and water thawing of frozen cod (*Gadus morhua*) have been reported by Merritt and Banks (1964) and Lorentzen and Pettersen (1966). A small weight gain of from 1 to 2 per cent was apparent for fish thawed in water and it was thought that this might affect the quality and provide excess drip from fillets. As a preliminary to pilot scale experiments on thawing of frozen fish in water, therefore, tests were carried out to compare the weight gain during humid air-blast and water thawing. The drip losses in fillets from the thawed fish were also compared. Following these tests a pilot scale water thawer with a capacity of 0.25 t/h was designed using data on water temperature, velocity and thawing time reported by MacCallum and Ellis (1964) and Merritt and Banks (1964) and erected at Ross Group (Hull) Ltd. Thirteen tons of fish were thawed and compared with fish thawed in the Ross Group air-blast thawer with respect to overall quality, weight changes and fillet yield. Mechanical operation of the thawer was also considered.

APPARATUS

Laboratory experiments

The experimental air-blast and water thawers have been described by Merritt and Banks (1964).

Pilot scale thawer

The layout of the thawer is shown diagrammatically in fig 1.

The thawer included an aluminium trough (1), 17 m long × 1.22 m wide × 0.56 m deep manufactured in 1.22 m flanged sections bolted together. A discharge tank 0.91 m long was added at the outlet end to allow thawed fish to drain. Ramps were fitted at the inlet and outlet ends for loading and discharge of fish.

The conveyor (2), consisted of two large roller Reynolds conveyor chains with 10.2 cm pitch and a 1,360 kg breaking strain connected to open mesh aluminium paddles (3), at 1.22 m intervals. These paddles guided the blocks along the trough whilst allowing the water to flow over the blocks. Water flow at a mean velocity of 0.46 m/min, slightly greater than the minimum advocated by MacCallum and Ellis (1964), was in the same direction as the fish.

The chains ran along the top flange of the trough and were restrained by aluminium channels, bolted to the flange, which kept the paddles in position. The chains were driven at the outlet end by a 1-hp motor with speed reduction through a Carter F12 variable speed gearbox fitted with a flange-mounted reduction gearbox (6). The speed was further reduced by a system of drive chains and sprockets.

Water was circulated by a stainless steel Wade centrifugal pump (5), rated at 8,200 l/h at 1.52 m head. Water was heated in a stainless steel shell and tube heat exchanger rated at 23.4 kW with a 56°C (100°F) temperature difference.

The water pipes, ball valves and strainer were of 5.08 cm bore Durapipe "V".

The strainer, fitted with a plastic mesh, was installed between two stop valves upstream of the pump. The thawer is shown installed alongside the Ross Group parallel-flow thawer in fig 2. (The cost of materials for this thawer was approximately £1,000.)

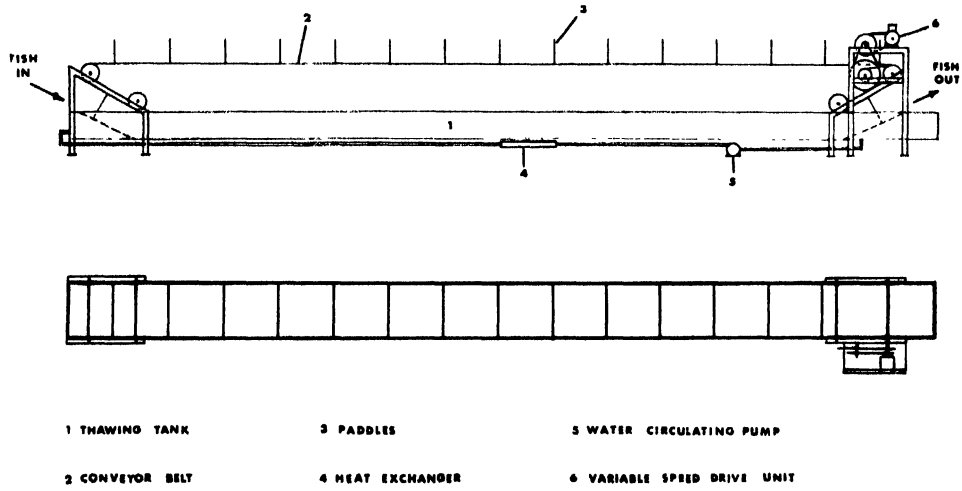


Fig 1. Diagrammatic layout of water thawer

Fig 2. Water thawer installed alongside Ross Group air-blast thawer

EXPERIMENTAL PROCEDURE

Laboratory experiments

Cod were caught by the Station's research trawler, *Sir William Hardy*, gutted, headed and frozen into 32-kg blocks within 1 h of landing on deck. Forty blocks were frozen and marked off in pairs. The blocks were then placed in −40°C (−40°F) cold store until required for thawing. These blocks were not glazed because it would have interfered with the measurement of weight changes and they remained in the store for only a short time.

Blocks were removed in pairs and weighed individually. They were then thawed simultaneously, one in the air-blast thawer and one in the water thawer with a fluid temperature between 15°C (59°F) and 21°C (70°F). Three blocks were thawed in 1 per cent salt solution at 18°C (65°F).

The thawed fish were then reweighed, filleted and the fillets weighed to determine the yield. Lots of 6 kg each were made up, weighed and packed in wooden boxes lined with parchment paper and some flake ice was added. The boxes were then placed in a chill room at 4.4°C (40°F).

The fillets were reweighed daily and returned to the chill after repacking and re-icing. They were inspected for bloom, firmness, gaping and appearance throughout the storage period and smoke cures were also examined.

Pilot scale experiments

Eight test runs were carried out between 2nd and 17th November 1966 using 45-kg blocks of sea-frozen whole cod, 107 × 50 × 10 cm thick. Details of thawing time and temperature are given in table 1.

TABLE 1. THAWING TIME AND FLUID TEMPERATURE

Run No.	*Load (t)*	*Inlet water temp. °C (°F)*	*Time in thawer (h)*
1	2	21 (70)	4.3*
2	1	21 (70)	3.5
3	1	18 (65)	4.0
4	1	21 (70)	4.0
5	2	18 (65)	4.0
6	2	18 (65)	4.0
7	2	18 (65)	4.0
8	2	18 (65)	4.0

* Reduced to 3 h after 1 t had passed through.

Fish were weighed before immersion, put through the thawer, sorted and weighed into 32-kg boxes. They were then kept overnight at ambient temperature until the filleting line was ready for them.

Fillet weights were obtained for hand and machine filleting both for water-thawed and air-blast thawed fish. In one instance fillets from whole fish thawed in air and water were stored overnight in a chill room 2.2°C (36°F) to determine the weight loss. Whole fish and fillets from Runs 3 and 4 were inspected for filletability and general appearance. For Runs 5 to 8 samples of whole fish from first-thawed and last-thawed fish from the water and air-blast thawers were subjected to taste panel tests to compare the overall quality. The Torry white fish score sheet for wet fish (Shewan *et al.*, 1953) and the provisional score sheet for the sensory evaluation of cooked thawed cod was used.

Fillets from thawed whole fish were examined the day after thawing and fillets from Run 8 were kept at chill temperatures, 2.2°C (36°F), for 11 days before subjection to tests.

Fish thawed by both methods were also examined bacteriologically to determine whether the counts increased throughout the day.

Twenty 9-kg blocks of frozen herring (*Clupea harengus*) were also thawed in water and a sample was subjected to taste panel tests.

RESULTS

Laboratory experiments

Weight changes during thawing. The mean weight gain for 17 blocks thawed in water was 1.59 per cent. Actual gains varied from 0.75 to 3.25 per cent. The mean weight loss for the same number thawed in air was 0.15 per cent with variation from 0 to 0.57 per cent. During the first 24 h of storage in the chill, fillets from water-thawed fish had lost 2.7 per cent weight and those from air-thawed fish 1.7 per cent. After 48 h the weight losses were 4.5 and 3.0 per cent respectively and during further storage this initial differential of 1.5 per cent was retained. Curves of mean weight loss during storage for fillets from the 34 blocks are shown in fig 3. Losses from individual lots of fillets varied by ±1.5 per cent from the mean curve throughout the storage period.

Fish thawed in 1 per cent salt solution had the same weight gain as fish thawed in fresh water.

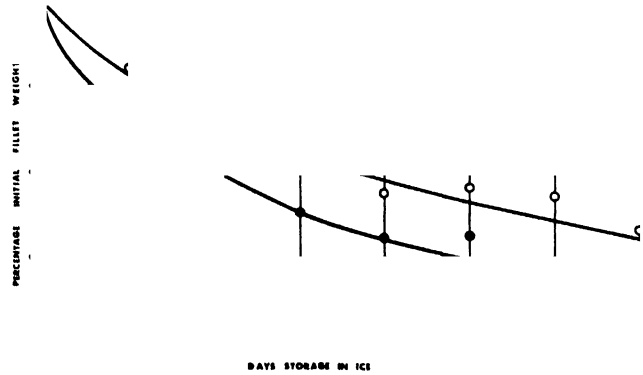


Fig 3. Weight loss in fillets stored in ice at chill temperature 2.2°C (36°F)

Fillet yield. The fillet yield was the same for both methods of thawing, the mean value obtained being 55 per cent.

Quality. Fish thawed in water tended to have a slight bleaching of the skin and generally felt warmer than those thawed in air. The condition of water-thawed fish was improved by reduction of the fluid temperature to 18°C (65°F). The fillets and smoke cures were good in all cases and there was no significant difference between the methods of thawing.

Pilot scale thawer tests

Mechanical operation. In general the plant operated satisfactorily but some difficulty was experienced with discharge arrangements. This was, in the main, due to the length of the paddles which was fixed by the depth of the

tank. The tank was deeper than necessary because, although there was no frothing in the pilot scale tests, there had been a considerable amount in the laboratory experiments mainly due to greater turbulence at a water velocity of 3 m/min. There was some stratification of the water in the pilot tests. On occasion blocks fouled with the paddles on the inlet ramp.

Drainage was also unsatisfactory because the drain was small and the trough was level. Filtration also presented a problem especially with herring. Scales from the herring and labels from the cod blocks very quickly choked the small strainer.

There was a marked reduction in performance of the heat exchanger during the period of the tests and upon inspection the tubes were found to be partially scaled up. Warm up of the water to operating temperature was slow, taking approximately 4 h.

Effect of temperature and immersion time. Whole fish thawed at 21°C (70°F) for 4 h 20 min in Run 1 were slightly overthawed and most of them would have been immediately filletable but these were unsuitable for Ross Group processing arrangements where the fish had to remain in ambient temperature overnight before filleting.

Fish thawed at 21°C (70°F) for 3 h 30 min were slightly bleached and, especially the smaller fish, were rather soft and warm. Fish thawed at 18°C (65°F) were much more evenly thawed after 4 h, but only 20 to 30 per cent would have been immediately filletable.

For Runs 5 to 8 the blocks were broken up manually after 3 h and the percentage thawed was greater than for unbroken blocks.

Fillets from fish thawed at 21°C (70°F) exhibited more gaping and a lack of firmness and bloom compared with fish thawed at 65°F both for machine and hand filleting. A few of the fillets from the smaller fish thawed at the higher temperature were slightly discoloured with a faintly brownish cut surface.

Quality. The taste panel results showed no significant difference between water thawed and air-thawed fish either as whole fish or fillets. No differences were observed between the first-thawed and last-thawed fish in each run. Quality was uniform throughout the tests although the fish were generally of slightly lower quality than the usual sea-frozen cod.

Fillets from fish held overnight after thawing were given slightly lower scores than whole fish immediately after thawing and a significant softening and drying of the muscle occurred after a further 24 h storage in the chill, There was a relatively small drop in score after 11 days' storage in the chill although samples were still well above the values considered acceptable.

No statistically significant difference in bacterial counts was shown between the fish thawed in the morning and those thawed in the afternoon. The counts were, however, significantly higher for air-thawed fish than for water-thawed fish.

The water-thawed herring were judged to be of very good quality. Bloom, appearance, odour and flavour were excellent.

Weight changes during thawing. The percentage weight change during thawing in water is shown in table 2.

TABLE 2. WEIGHT CHANGE DURING THAWING. PILOT SCALE WATER THAWER

Run No.	*% Change*	*Temperature °C (°F)*
4	+0.25	21 (70)
2	−1.92	21 (70)
3	−0.35	18 (65)
4	−1.69	21 (70)
5	+0.88	18 (65)
6	−0.44	18 (65)
7	−0.75	18 (65)
8	−0.45	18 (65)

The percentage weight changes in the air-blast thawer found by Hewitt and Cruickshank (1966) are shown in table 3.

TABLE 3. WEIGHT CHANGE DURING THAWING IN AIR-BLAST THAWER

Date	*Change (%)*	*Temperature °C (°F)*
19th April 1966	+0.20	20.6 (69)
20th April 1966	−1.49	23.9 (75)
21st April 1966	−0.52	22.8 (73)

Fillet yield. Yield figures were obtained for Runs 3 to 8 and are compared with some yield figures from air-blast thawed fish in table 4. In both cases where comparative yields could be obtained the yield was better from water-thawed than from air-blast thawed fish, but tests were too few and no firm conclusion should be drawn. No figures were obtained for machine-filleted air-blast thawed fish but a direct comparison of machine filleting would be of interest.

TABLE 4. YIELD FIGURES FOR AIR-BLAST AND WATER-THAWED FISH

Run No.	*Weight*	*Filleted*	*Yield*	
			Air	*Water*
	(kg)		(%)	(%)
3	540	hand		48.8
4	510	hand		46.8
	160	machine		46.6
5	1,780	hand		48.2
	2,790	hand	46.4	
6	890	hand		46.7
	2,540	hand	46.1	
7	1,520	hand		47.4
8	2,220	machine		41.5*
	1,020	hand		46.3

* Skinned fillets.

Weight change after overnight chill storage. 3.6 kg each of fillets from air-blast thawed and water-thawed whole fish stored overnight in the chill lost 2.7 and 1.5 per cent weight respectively. This is almost exactly the reverse of laboratory experiments but there was only one test.

Laboratory experiments

The magnitude of weight gains during water thawing is in agreement with that experienced by Lorentzen and Pettersen (1966) but the slight gain they obtained with air-blast thawing did not occur in these tests. The weight gained in water thawing was lost as drip within a very short period in these tests and this was surmised by Lorentzen and Pettersen (1966). There was no significant

difference in fillets from whole fish thawed by both methods with respect to appearance and ability to produce good smoke cures.

Pilot scale experiments

Operation of plant. The operation of the plant could be improved considerably with a small increase in cost. A large heat exchanger would be necessary especially for quick warm up and also to give due allowance for scaling Large drains together with a slope in the trough would permit the trough to be emptied quickly and a large main would be necessary for quick refilling. A large self-cleaning filter would be necessary to minimize maintenance. Continuous draining with the introduction of a small amount of make-up water might reduce these problems.

Blocks were easily broken up manually after 3 h giving a more uniform and complete thaw in the 4-h period. It should be possible to achieve break-up automatically but this would complicate the design.

A higher mean water velocity than that employed would improve turbulence and prevent some of the stratification which occurred, ensuring that the water velocity at all points is adequate, thus increasing the heat transfer rate. MacCallum and Ellis (1964) experienced frothing at a velocity of 1.2 m/min but, if a higher velocity, below this value, did not produce frothing, a shallower trough could be used which would improve discharge, although a discharge conveyor would still be necessary. Side loading would also be advantageous as this would prevent blocks fouling the paddles at entry. As the thawer tends to be rather long, floor space could be reduced if a two- or three-tier arrangement were adopted.

Temperature and thawing time. As found in the laboratory experiments, the maximum water temperature should be 18°C (65°F), since, above this temperature, the fish become too soft and excessive gaping of the cut surface occurs on filleting. A time of 4 h in the thawer appears to be suitable if there is to be a delay before filleting.

Quality. The results of quality assessments are in agreement with Merritt and Banks (1964) and Lorentzen and Pettersen (1966). The quality of herring thawed in water was very good and an added advantage from the curing aspect was that they had been virtually descaled and washed clean.

Weight changes and yield. The increase in weight during thawing experienced in the laboratory experiments was not upheld. This may be due to the following factors:

(1) Incomplete bleeding of fish before freezing so that more blood is left to run out during thawing.

(2) More ice in the frozen blocks which would melt during thawing.

(3) Intrinsic differences, fish from different grounds, different water and lower water velocity.

It is probably significant that more weight was lost from fish thawed at a higher temperature in both air-blast and water thawers, tables 2 and 3, as factors (1) and (2) above may be somewhat dependent on temperature.

The mean yield figures obtained are in agreement with those of Lorentzen and Pettersen (1966) for moist air and water thawing of single whole fish.

CONCLUSIONS

(1) Water thawing on a commercial scale is a feasible proposition.

(2) Water-thawed fish is similar in quality to fish thawed in humid air-blast thawers.

(3) Weight changes in water thawing on a commercial scale will be within acceptable limits.

(4) Fluid temperature should be restricted to a maximum of 18°C (65°F) for cod and herring.

(5) A continuous water thawer would be considerably cheaper than a corresponding air-blast thawer.

(6) Essential alterations to the existing design are a larger heat exchanger, a discharge conveyor, a self-cleaning filter, improved drainage and a larger pump.

Acknowledgments

The pilot scale work was carried out with the co-operation of Ross Group (Hull) Ltd. who supplied the factory space, services and the fish. J. Horne assessed the quality of the fish in the laboratory and for Runs 3 and 4. Mrs. E. I. Livingston supervised the taste panel work. The work described in this paper was carried out as part of the program of the Ministry of Technology.

References

HEWITT, M R and CRUICKSHANK, G 1966 Unpublished results. Torry Research Station, Aberdeen.

LORENTZEN, G and PETTERSEN, R J 1966 *Kjoletek. FrysNaer.*, **1**, 3.

MACCALLUM, W A and ELLIS, D G 1964 *J. Fish. Res. Bd Can.*, **21**(1), 115.

MERRITT, J H and BANKS, A 1964 Thawing blocks of frozen cod in air and in water. *Annex 1964–1 Bull. int. Inst. Refrig.*, 65–80.

SHEWAN, J M, *et al.* 1953 *J. Sci. Fd Agric.*, **4**, 283.

Essai d'application de la méthode de décongélation électronique à la sardine congelée destinée à la conserve

par J. R. Crépey et D. Mairey

Essai d'application de la méthode de décongélation électronique à la sardine congelée destinée à la conserve

L'utilisation du poisson congelé comme matière première pour l'industrie de la conserve pose un certain nombre de problèmes parmi lesquels figurent les difficultés de la décongélation. L'obtention d'une décongélation rapide est d'un intérêt primordial pour limiter les risques d'altération et de contamination. On a tout naturellement pensé à l'emploi du chauffage électronique qui semble, par sa nature même, pouvoir remédier aux inconvénients des méthodes habituelles à l'air ou à l'eau.

L'Institut Scientifique et Technique des Pêches Maritimes (ISTPM) a rencontré dans son étude consacrée à la sardine, les mêmes difficultés qu'avec les espèces le plus couramment expérimentées, du fait, notamment, de l'hétérogénéité structurale des blocs de poisson congelé. Les constituants de celui-ci ont en effet des constantes diélectriques différentes, ce qui provoque des absorptions inégales d'énergie; il en résulte des températures exagérément élevées par endroits, et insuffisantes dans d'autres.

Le problème se complique avec la sardine, en raison d'une part de la fragilité du poisson, d'autre part de la nécessité de procéder à l'éviscération avant la mise en conserve, opération qui ne peut s'effectuer convenablement qu'à des températures positives.

L'ISTPM a étudié l'influence de la densité de puissance, de la quantité d'énergie, de la fréquence et du mode d'application de l'énergie. Malgré un certain nombre de remèdes apportés, il semble qu'il soit difficile d'obtenir un chauffage uniforme, surtout au voisinage de la zone de fusion.

Les essais ont été conduits conjointement avec des décongélations à l'eau et à l'air, en utilisant des appareils spécialement construits à l'ISTPM.

Les auteurs donnent les résultats comparatifs obtenus dans les divers cas envisagés.

Trials on electronic thawing applied to frozen sardines for canning

The use of frozen fish as a raw material for the canning industry raises a number of problems, one of which is the difficulty of thawing out. Rapidity in the latter process is of utmost importance in order to limit the risk of spoilage and contamination, and it was only to be expected that the use of electronic heating which, by its very nature, seems capable of overcoming the drawbacks of the usual methods of thawing by air or by water, would be considered.

In its research on sardines, the Institut Scientifique et Technique des Pêches Maritimes (ISTPM) has met with the same difficulties as with more widely-tested species, mainly because of the structural heterogeneity of the blocks of frozen fish. The components of frozen fish have different dielectric constants, which cause irregular absorptions of energy; this results in temperature being too high in some parts and too low in others.

In the case of sardines the problem is more complicated, due on the one hand to the fragility of the fish and, on the other, to the need to perform evisceration before canning, an operation which can only be properly performed at temperatures above freezing point.

The ISTPM has studied the influence of the power density, quantity of energy and the frequency and method of application of that energy. Despite a number of expedients, it seems to be difficult to obtain even heating, especially in proximity to the thawing layer.

The tests were conducted together with defrosting by water and air, using equipment specially built for this purpose at the ISTPM.

The findings for the different cases examined are compared.

Ensayo de aplicación del metodo de descongelación electrónica a la sardina congelada destinada a la conserva

El empleo del pescado congelado como materia prima para la industria de la conserva plantea algunos problemas entre los cuales figuran las dificultades de la descongelación. La obtención de una descongelación rápida es de interés primordial para limitar los riesgos de alteración y de contaminación. Se ha pensado en el empleo del calentamiento electrónico que, por su naturaleza misma, parece que puede remediar los inconvenientes que tienen los métodos habituales que utilizan aire o agua.

En su estudio consagrado a la sardina, el Institut scientifique et technique des pêches maritimes (ISTPM) ha encontrado las mismas dificultades que con las especies experimentadas más frecuentemente, debido especialmente a la heterogeneidad estructural de los bloques de pescado congelado. Los componentes de éste poseen, en efecto, constantes dieléctricas diferentes, lo que provoca desiguales absorciones de energía; de ello resultan temperaturas exageradamente elevadas en ciertas partes e insuficientes en otras.

El problema se complica con la sardina, debido, por una parte, a la fragilidad de tal pescado, y por otra, a la necesidad de proceder a la evisceración antes de realizar la conserva, operación que sólo se puede efectuar convenientemente a temperaturas positivas.

El ISTPM ha estudiado la influencia de la densidad de potencia, de la cantidad de energía, de la frecuencia y del modo de aplicación de la energía. A pesar de algunos remedios aportados, parece que es difícil obtener un calentamiento uniforme, sobre todo en la proximidad de la zona de fusión.

Las pruebas se han realizado conjuntamente con descongelaciones en agua y en aire, utilizando equipo especialmente construido en el ISTPM.

Los autores dan a conocer los resultados comparativos obtenidos en los diversos casos considerados.

L'UTILISATION du poisson congelé comme matière première pour l'industrie de la conserve permet aux fabriques de pallier rapidement les carences d'approvisionnement en poisson frais. Mais cela pose un certain nombre de problèmes, parmi lesquels les difficultés de la décongélation. L'obtention d'une décongélation rapide est en effet primordiale pour limiter les risques d'altération et de contamination.

Les deux systèmes employés le plus couramment, la décongélation à l'air et la décongélation à l'eau, utilisent un phénomène centripète, le réchauffement s'opérant à travers une zone d'épaisseur croissante dont la conductivité thermique augmente considérablement au cours du changement d'état.

Dans la décongélation par pertes diélectriques, les calories ne proviennent pas d'un apport extérieur de chaleur mais sont produites dans la masse elle-même et théoriquement dans tous les points du diélectrique.

Les diverses publications de ces dernières années ont montré que des résultats satisfaisants peuvent être obtenus par cette méthode sous certaines conditions.

RAPPEL DU PRINCIPE DU CHAUFFAGE PAR PERTES DIELECTRIQUES

Lorsqu'un corps non conducteur de l'électricité, également appelé diélectrique, est placé dans le champ qui règne entre les deux armatures d'un condensateur, les électrons périphériques de ses atomes sont sollicités vers l'électrode positive, et tendent à s'orienter suivant le champ électrique en absorbant de l'énergie.

Ces mouvements moléculaires s'accompagnent de frottements qui transforment en chaleur et de façon irréversible une partie de l'énergie empruntée au champ. Lorsqu'on inverse la polarité des électrodes, les molécules tendent alors à pivoter pour s'orienter dans le même sens que le nouveau champ. Si les électrodes sont alimentées en tension alternative, les frottements moléculaires se succèdent proportionnellement à la fréquence. Une quantité de chaleur naît au sein du diélectrique à raison de 0,239 calorie pour chaque W/s absorbé.

La formule suivante donne la puissance dissipée en chaleur dans le diélectrique:

$$P = \frac{0{,}555 f \varepsilon E^2 tg\delta V}{d^2}$$

P en watt
E en volt
f en MHz
V en cm^3
d en cm (écartement des électrodes)

La constante diélectrique ε et le facteur de perte $tg\delta$ caractérisent les propriétés d'une substance du point de vue diélectrique.

EQUIPEMENT UTILISE

Le générateur électronique qui a été utilisé pour les essais peut couvrir une plage de fréquences de 25 à 45 MHz; sa puissance maximale atteint 6 kW.

L'enceinte de décongélation, construite au laboratoire, est un parallélépipède d'aluminium fermé par une porte en métal perforé facilitant les observations visuelles. L'électrode de masse est constituée par le plancher du four et l'électrode de tension est suspendue par l'intermédiaire d'isolateurs à quatre tiges filetées permettant son réglage en hauteur. La puissance de travail peut de la sorte être dosée à volonté.

La répartition du champ électrostatique est améliorée par l'interposition d'une électrode supplémentaire, isolée électriquement, que l'on place à 1 ou 2 cm au-dessus du bac contenant le poisson.

Le four n'est pas équipé de convoyeur, mais des résultats similaires sont obtenus par l'adoption de régimes de chauffage appliqués par fractions successives, entrecoupées de périodes d'arrêt. L'équipement est ainsi moins onéreux et l'utilisation plus souple.

Les dimensions de l'ensemble permettent de traiter des blocs de 5, 10 et 20 kg. Les plus utilisés pour les essais présentement décrits sont ceux de 5 kg (370 × 260 × 65 mm) qui correspondent à un module normal de sardines congelées.

Le matériel d'expérience de qualité constante est toujours congelé par nos soins à −40°C (−40°F) et entreposé à −20°C (−4°F).

DIFFICULTES RENCONTREES

La simple application du principe du chauffage par pertes diélectriques ne semble pas, à priori, présenter de difficultés majeures. On peut penser, en effet, qu'il suffit de placer un bloc de poisson congelé entre les électrodes d'un four, celles-ci étant soumises à une tension alternative convenablement choisie, pour obtenir le dégagement de chaleur voulu.

Pourtant, la mise en oeuvre du procédé sans précaution ne saurait donner les résultats escomptés. Il est indispensable notamment:

que la tension à utiliser ne soit pas trop forte pour éviter la formation d'arcs;

que la puissance de travail ne dépasse pas une certaine valeur, sinon des brûlures se produisent à la surface des blocs de poisson;

que la fréquence qui conditionne la répartition du champ et l'absorption de l'énergie produite soit judicieusement choisie.

Malgré cela, la décongélation ne s'opère pas forcément dans des conditions satisfaisantes, et d'autres limitations se manifestent en raison de la tendance à l'hétérogénéité de la production de chaleur.

On s'aperçoit en effet que la température ne varie pas également dans toute la masse. Ceci tient à deux causes:

(1) D'une part, un bloc de poisson congelé n'est pas une matière homogène, il renferme des poches d'air et des inclusions de glace. La constitution du poisson lui-même n'est pas uniforme et peut varier notablement suivant qu'il s'agit de la tête, des parties osseuses, des muscles ou des viscères. La constante diélectrique de la matière n'est donc pas la même en tous les points, et cette hétérogénéité structurale provoque dès le début de l'opération, un dégagement de chaleur inégalement réparti.

(2) D'autre part, pendant le chauffage, l'ordre de grandeur des propriétés diélectriques ε et δ augmentent très rapidement, surtout lorsqu'on approche de la zone de fusion (Bengtsson, 1963; Jason et Sanders, 1962).

L'hétérogénéité initiale du dégagement de chaleur ne peut donc que s'accroître au cours de la décongélation, par absorption d'énergie de plus en plus importante par les zones déjà réchauffées au détriment des zones voisines qui deviennent plus froides.

Nous avons effectivement enregistré des écarts de l'ordre de 25°C (77°F), après alimentation du système d'électrodes en énergie suffisante pour obtenir la production de chaleur nécessaire au réchauffage et à la décongélation. De plus, lors d'essais conduits dans le but d'achever complètement la décongélation dans toutes les parties du bloc, les écarts se sont révélés beaucoup plus importants, provoquant des cuissons locales, tandis que la température des régions voisines n'augmentait que très lentement.

Par ailleurs, les tentatives de décongélation par application de la totalité de l'énergie nécessaire en une seule fois n'ont pas donné de bons résultats, aussi bien en utilisant une puissance importante pendant un temps réduit, qu'une puissance plus faible pendant un temps plus long.

D'une manière générale, les défauts constatés sont de deux ordres, pouvant se produire au cours d'un même essai:

cuisson partielle;
adhérences entre les surfaces en contact.

L'adhérence se produit lorsqu'il reste de la glace qui maintient en contact deux poissons ou des filets de poisson; elle est plus prononcée avec des filets sans peau. L'adhérence peut aussi exister quand tout le poisson est décongelé.

Nous nous sommes donc efforcés, sinon d'éliminer totalement, du moins de réduire ces défauts, soit en immergeant les blocs dans l'eau ou la glace, soit en appliquant l'énergie par fractions successives, soit en combinant les deux.

De nombreux essais furent nécessaires pour déterminer les conditions les plus favorables et préciser l'influence des variables, comme les dimensions des électrodes, le rapport de leur surface à celle du bloc à décongeler, la puissance par unité de poids, la quantité d'énergie, la forme et la durée du cycle. Ils ont porté sur la décongélation à 35 MHz de blocs de poissons entiers ou de filets de différentes espèces notamment cabillauds, merlans, plies, dorades, sébastes, maquereaux et harengs.

Nous avons été amenés ainsi à adopter les conditions de travail suivantes:

l'immersion dans l'eau;
l'application fractionnée de l'énergie;
la diminution de la charge à chaque passage, au fur et à mesure du réchauffement du poisson (fig 1).

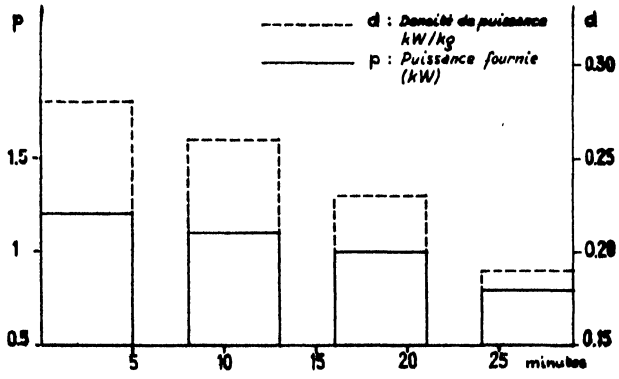


Fig 1. Exemple de cycle de décongélation à 35 MHz

D'une façon générale quelles que soient les combinaisons employées, les essais ont démontré qu'il est nuisible de dépasser une certaine quantité d'énergie et que, même en appliquant une très faible densité de puissance de l'ordre de 200 W/kg, des dégagements incontrôlables de chaleur, plus ou moins accentués d'un essai à l'autre se produisent à l'approche de la zone critique de décongélation.

APPLICATION A LA SARDINE (*Sardina pilchardus*)

Fréquence de 35 MHz

Les essais précédents furent repris systématiquement à 35 MHz, seule fréquence obtenue à l'origine du générateur avec des blocs de sardines de 5 kg environ. En jouant sur les différents facteurs qui influent sur la répartition du champ nous sommes arrivés à limiter notablement les points de surchauffe, sans toutefois obtenir avec régularité une répartition homogène de la température, mais du moins, en éliminant totalement les risques de cuisson.

L'analyse du tableau 1, qui groupe les résultats de quelques essais types choisis parmi les plus représentatifs, démontre qu'il est nuisible de dépasser une certaine quantité d'énergie située aux environs de 100 à 140 Wh/kg. De même la densité de puissance limité à 0,3 kW/kg, au début de l'opération, doit être réduite progressivement, pour tomber aux environs de 0,2 kW/kg aux approches de la décongélation proprement dite.

La fig 2 donne un modèle de répartition de la température à l'intérieur du bloc de sardines après alimentation du four en énergie nécessaire au chauffage et à la décongélation.

Les mesures de températures ne pouvant avoir lieu pendant le fonctionnement du générateur, celles-ci sont relevées le plus rapidement possible après l'arrêt à l'aide de sondes fines à thermorésistances.

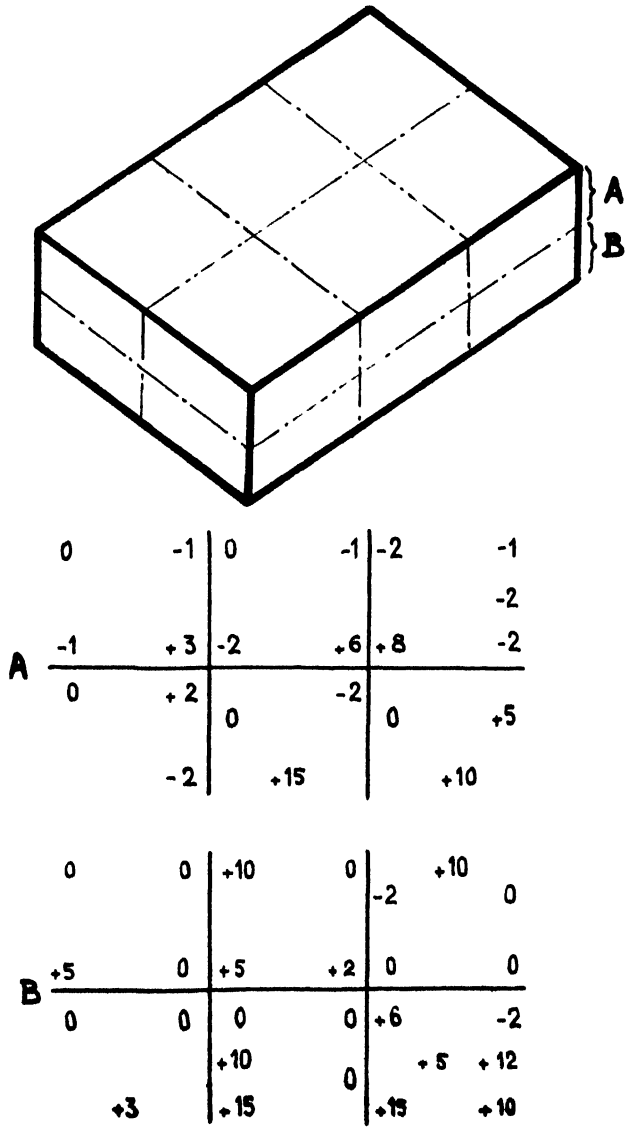


Fig 2. Exemple de répartition des températures dans un bloc de sardines chauffé par effet diélectrique (°C)

TABLEAU 1. DÉCONGÉLATION À 35 MHZ

C	*R*	*P*	*W*	*E*	*Tu*	*K*	*M*	*Observ.*
A1	0,3	3,5	0,26–0,23	120	30	0,67	S	M/s+
A1	0,3	3,5	0,31–0,33	155	20	0,69	E	M/c
A1	0,3	3,5	0,56–0,43	90	10	0,40	S	M/s+/a+
A1	0,6	9	0,12–0,13	120	50	0,65	E	M/c
A2	0,7	4,5	0,37–0,15	135	28	0,58	S	M/s+
A2	0,7	4	0,40–0,18	165	30	0,60	E	M/c
A	0,7	4,5	0,40–0,17	105	20	0,69	E	AB/a
A	0,7	3,5	0,30–0,21	100	25	0,68	S	AB/s
A	0,7	4,5	0,25–0,19	100	28	0,65	E	B
A2	0,7	4,5	0,26–0,19	100	28	0,65	E	B
A2	0,7	4,5	0,27–0,18	100	28	0,65	S	B
A	0,7	4,5	0,26–0,18	100	26	0,72	E	B
B3	1	4,5	0,27–0,22	115	30	0,60	E	AB
B4	1	9	0,27–0,21	120	30	0,60	E	B

C Combinaisons d'électrodes:
électrode d'alimentation: A, 300 × 250 mm
B, 240 × 240 mm
électrode de chauffage 1, 600 × 500 mm
2, 480 × 280 mm
3, 370 × 260 mm
4, 530 × 385 mm
R Rapport surface de poisson/surface d'électrode
P Poids du bloc à décongeler (kg)
W Puissance fournie au début et à la fin de l'essai (kW/kg)
E Energie dépensée (Wh/kg)
Tu Durée de fonctionnement du générateur (minutes)
K Rapport durée de fonctionnement/durée totale
M Mode opératoire: E, avec immersion dans l'eau; S, à sec
Observations: M, mauvaise décongélation
AB, assez bonne
B, bonne décongélation
Défauts: s, quelques surchauffes locales; s +, surchauffe importante
c, température excessive à la périphérie
a, adhérences faibles entre poissons; a+, adhérences fortes

Le diagramme de la fig 3 représente l'évolution de la température dans un bloc de sardines au cours d'une décongélation à 35 MHz. Les valeurs portées sont des moyennes qui reproduisent aussi fidèlement que possible la température de l'ensemble des individus d'un bloc, à l'exclusion des points de surchauffe, d'ailleurs très limités.

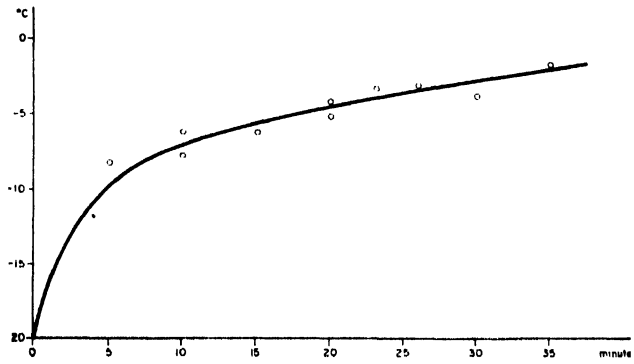


Fig 3. Evolution de la température d'un bloc de sardines au cours du chauffage électronique

En résumé, on peut considérer qu'un bloc de sardines de 5 kg peut être réchauffé de −20°C (4°F) à −2°C (28,4°F) dans des conditions acceptables en lui fournissant une énergie de 100 Wh/kg par fractions de 5 min pendant 25 à 30 min. Au-dessus de −2°C (28,4°F), la remontée de température pose de nouveaux problèmes, liés à la variation brusque des propriétés diélectriques qui accompagnent le changement d'état.

Exigences de la mise en conserve de la sardine

Malgré les précautions prises et les artifices employés il semble donc difficile, à la fréquence de 35 MHz, de pousser l'élévation de température au delà de la zone critique de changement d'état sans risque de dommages.

Pourtant l'obtention d'une température positive, dans l'ensemble du corps des sardines, est indispensable pour pouvoir procéder convenablement à l'étêtage et à l'éviscération qui doivent être réalisés avant la mise en conserve.

Pour cette raison le chauffage électronique s'avère ici d'un emploi plus délicat que dans le cas de la décongélation de blocs de filets ou même de poissons entiers simplement destinés à la vente en l'état.

La fragilité de la sardine constitue d'ailleurs un handicap certain et la température n'est pas le seul facteur qui influe sur la difficulté de l'éviscération. L'autolyse favorise également les déchirures de la paroi abdominale et même à l'état frais l'éventration est fréquente sur des poissons légèrement "fatigués".

Quoi qu'il en soit, il convient de poursuivre la décongélation jusqu'à une température telle que l'ensemble des individus s'éviscère convenablement mais sans franchir un certain seuil sous peine d'éventration (fig 4).

Améliorations envisagées

En utilisant la fréquence de 35 MHz il apparaît donc nécessaire de laisser en attente les sardines à la sortie du four pour permettre une égalisation de la température sans échauffement excessif du poisson qui conduirait à des éventrations.

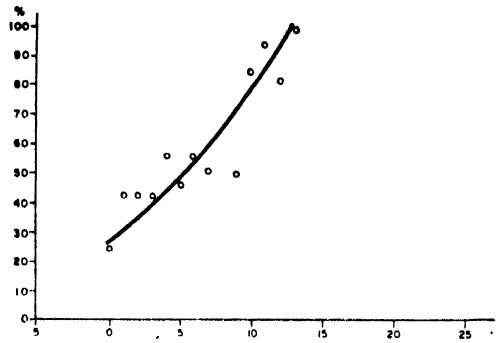


Fig 4. Pourcentage de sardines qui s'eviscèrent aux diverses températures

Pour remédier à cet inconvénient et améliorer les conditions de traitement, deux solutions ont été envisagées:

(1) Associer le chauffage électronique et la décongélation à l'eau: dans le cas des blocs de sardines dont certains individus sont rapidement portés à une température voisine du point de fusion les échanges thermiques sont facilités par l'augmentation des surfaces de contact due à la séparation des poissons entre eux.

(2) Utiliser des courants de fréquence plus élevés puisque la variation des constantes diélectriques en fonction de la température diminue quand la fréquence augmente (Bengtsson, 1963).

Nous avons choisi d'expérimenter cette dernière possibilité en encadrant, pour confirmation, la fréquence initiale, soit: 25 et 45 MHz.

Fréquences de 25 et 45 MHz

Comme il fallait s'y attendre la fréquence de 25 MHz expérimentée de façon analogue à 35 MHz, n'a pas paru apporter d'amélioration, mais plutôt une aggravation des défauts, particulièrement en ce qui concerne les adhérences au centre des blocs.

En revanche, malgré un accroissement de fréquence relativement faible, les essais à 45 MHz semblent permettre une décongélation plus rapide en employant une puissance par unité de volume plus importante, même au voisinage de la fusion, sans que la surchauffe s'aggrave pour autant (fig 5). Les résultats furent suffisamment encourageants pour que le laboratoire s'équipe en vue de fréquences plus élevées encore. Les essais sont en cours.

COMPARAISON AVEC LES METHODES CLASSIQUES

Dans le but de faire ressortir les avantages ou les inconvénients de la méthode de décongélation électronique, nous avons entrepris des essais comparatifs de décongélation par l'eau et par l'air. Les conditions de température ont été volontairement limitées à celles qui paraissent les plus aptes à sauvegarder les qualités du produit.

Décongélation à l'air calme

Un bloc de sardines congelées est disposé au centre d'un caisson à double enveloppe, dont la température intérieure peut être réglée à volonté. Une sonde indique l'ambiance du caisson, pendant que d'autres placées dans le muscle dorsal d'un poisson renseignent sur l'évolution de la

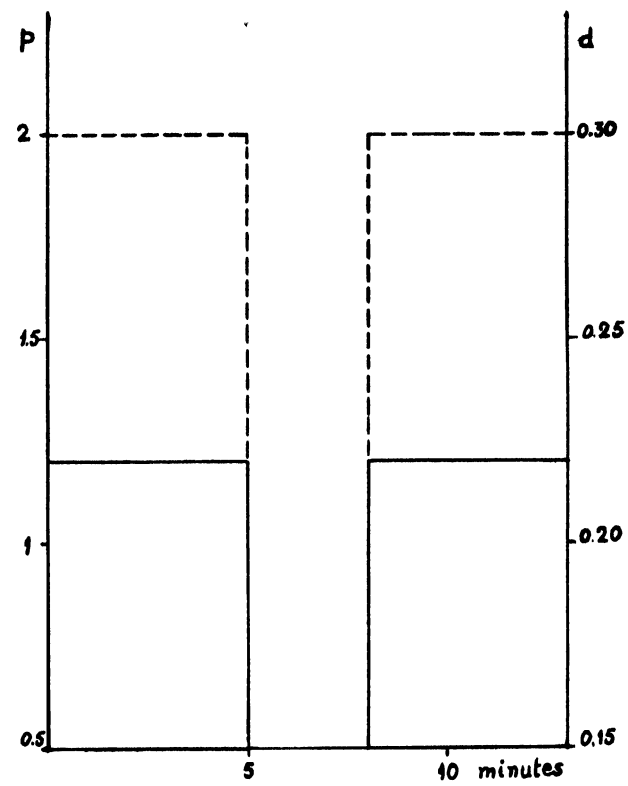


Fig 5. Exemple de cycle de décongelation à 45 MHz; p, *puissance fournie (kW);* d, *densité de puissance (kW/kg)*

température à différentes profondeurs. Les sondes sont toutes raccordées à un pont de Wheatstone enregistreur.

En considérant la fig 6 on peut se rendre compte qu'il faut environ 18 h pour que les poissons situés au centre du bloc atteignent 0°C (32°F) lorsque l'ambiance est à 8°C (46°F).

Décongélation dans l'air en mouvement

La fig 7 représente l'enregistrement des températures à différents niveaux dans un bloc placé dans une cellule ventilée maintenue à 8°C (46°F).

On constate que pour atteindre 0°C (32°F) il faut encore 11 h dans les sardines situées au centre du bloc et 3 h dans celles de la périphérie.

Décongélation à l'eau courante

Afin de disposer d'un bain à température convenable, nous avons construit un bac d'essais muni d'un réservoir d'alimentation d'une capacité suffisante pour permettre le recyclage de l'eau sans renouvellement pendant une opération. L'ensemble est thermostaté à température réglable et une pompe électrique dont le débit peut varier à volanté de 0 à 2 400 l/h assure la circulation de l'eau.

Le bloc de poisson disposé sur une claie inoxydable se trouve directement dans le courant d'eau. Sa température est mesurée par sonde de la même façon que pour les décongélations à l'air.

Dans un courant d'eau à 8°C (46°F) avec un débit de 120 l/h, la durée de la décongélation excède encore 4 h malgré un certain éparpillement des sardines périphériques (fig 8).

Il faut remarquer cependant que le travail du poisson en vue de la mise en conserve peut, de ce fait, débuter

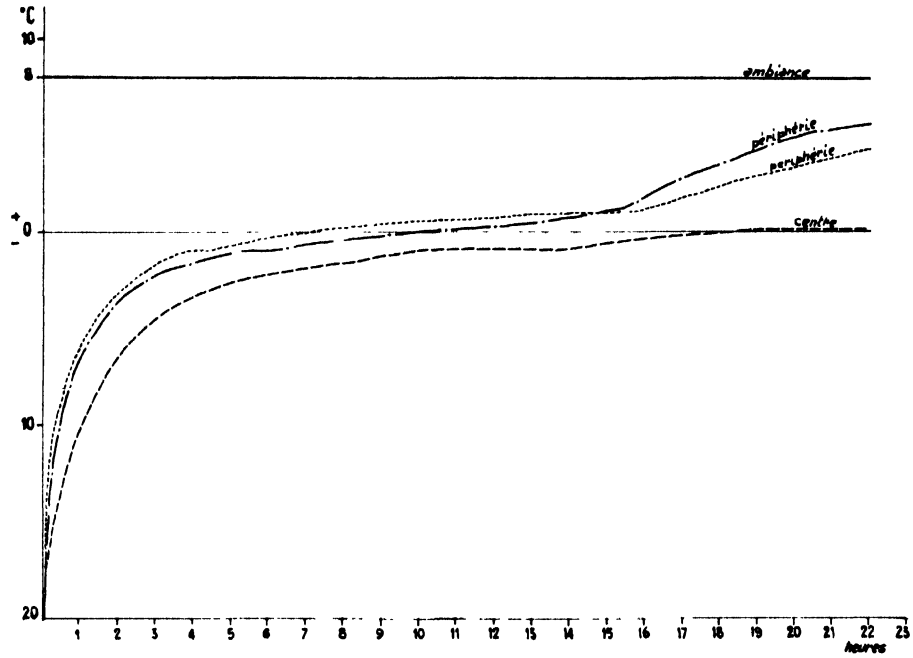


Fig 6. Sardines: Décongèlation dans l'air calme

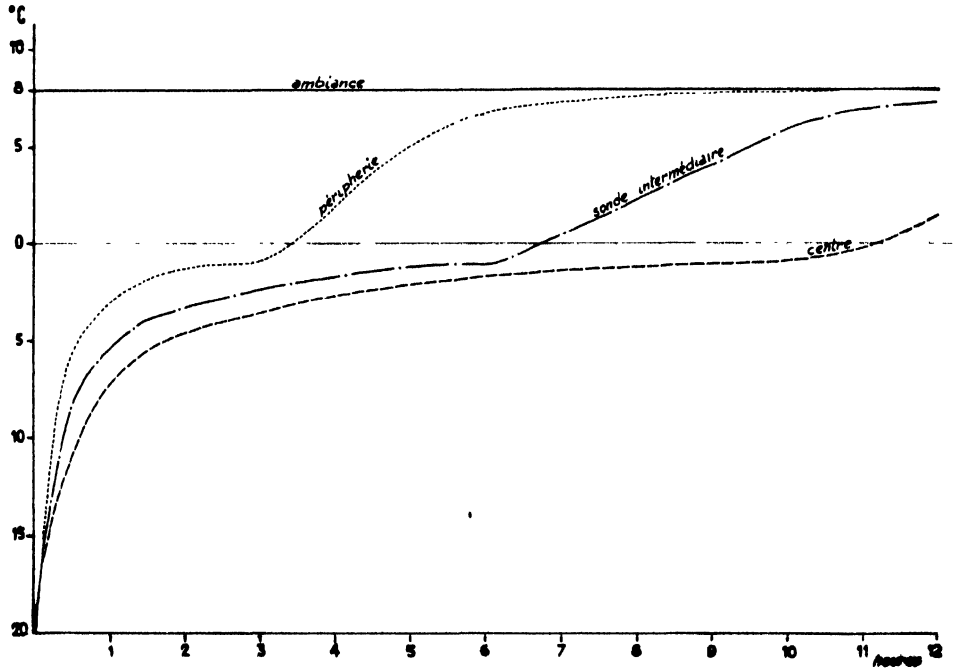


Fig 7. Sardines: Décongèlation dans l'air ventilé

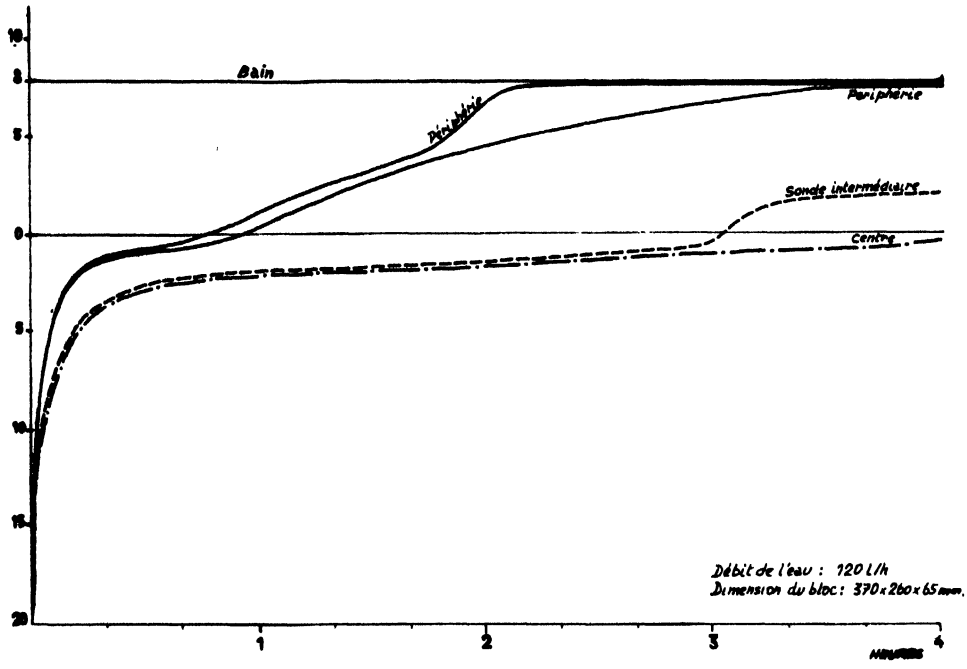


Fig 8. Sardines: Décongèlation à l'eau

avant la décongélation complète du bloc comme l'indiquent les courbes de température des sardines périphériques.

QUALITE DU POISSON

Bien que des mesures précises de la qualité du poisson décongelé par les différentes méthodes n'aient pas été faites, les observations et les examens organoleptiques effectués régulièrement après chaque opération ont montré que les sardines décongelées par chauffage diélectrique avaient une meilleure apparence et conservaient en général une meilleure tenue que celles qui avaient été traitées par les autres méthodes.

CONCLUSIONS

L'utilisation de la haute fréquence à 35 MHz peut permettre de réchauffer en 25 min environ un bloc de sardines de −20°C (−4°F) à une température moyenne −2°C (28,4°F) environ, telle que l'ensemble des poissons soit à la limite de la décongélation.

La comparaison avec les méthodes classiques fait ressortir la rapidité du chauffage diélectrique.

De plus, malgré ses imperfections et les risques de pertes qui peuvent résulter de certaines difficultés d'éviscération, la décongélation électronique aboutit à un produit qui présente une qualité apparente supérieure à celle que l'on obtient avec les autres méthodes.

Bibliographie

BENGTSSON, N E 1962 Experiments with dielectric defrosting of meat and fish. *Proc. I int. Congr. Fd Sci. Technol.*, London, 17th–20th September.

BENGTSSON, N E 1963 Electronic defrosting of meat and fish at 35 and 2·2450 MHz. A laboratory comparison. *Fd Technol., Champaign*, **17**(10), 97.

BENGTSSON, N E, *et al.* 1963 Measurements of the dielectric properties of frozen and defrosted meat and fish in the frequency range 10–200 MHz. *J. Sci. Fd Agric.*, **14**, August.

BOURY, M 1958 La sardine congelée. *Revue Trav. Inst. (scient. tech.) Pêche marit.*, **22**(3).

JASON, A C and SANDERS, H R 1959 Dielectric thawing of fish. *Proc. X int. Congr. Refrig.*, Copenhagen, **3**, 19.

JASON, A C and SANDERS, H R 1962 Dielectric thawing of fish. Parts 1 and 2. *Fd Technol., Champaign*, **16**(6), 101.

MACCALLUM, W A 1964 Temperatures and thaw drip associated with electronic thawing of Newfoundland cod. *J. Fish. Res. Bd Can.*, **21**(4).

Influence of Thawing and Thawing Methods on the Immediate and Refrozen Storage Quality of Fish

by W. A. MacCallum and D. R. Idler

(with addendum by H. C. Freeman and D. R. Idler—Green discolouration in flounder)

Influence of thawing and thawing methods on the immediate and refrozen storage quality of fish

This report concerns the:

(1) Appearance, characteristics and uses of trawler-frozen cod (*Gadus morhua*), flounder (*Hippoglossoides platessoides*) and redfish (*Sebastes marinus mentella*) after thawing.

(2) Comparative effects of thawing methods on sensory, organoleptic and chemical evaluation of the fish prior to and after the second freezing and cold storage.

(3) Influence of holding and holding media during chilled storage of the thawed fish prior to the second freezing.

(4) Weight losses occurring on thawing during post-thaw holding at about 0°C.

None of these fish, if freshly frozen at sea, carry spoilage odours on thawing.

Upon thawing, gutted, headed cod may be discoloured (brown) at the cut surfaces. This aspect can affect yields upon filleting but does not affect unfrozen or refrozen quality. Freezing at sea heads-on would improve the appearance of thawed cod "dressed" for "fresh" sales.

The fillets removed from headed cod and gutted flounder after thawing can be darker (tending to a green hue) than those prepared from fish landed in ice. There was no evidence that material of off-white colour possessed different taste or texture characteristics from normally "white" fillets. The discolouration persisted in frozen storage if present in fillets (flounder) of thawed fish. It is not known whether the colour in the cold-stored pack was more pronounced than encountered in some frozen fish prepared from iced-at-sea landings (*see* Addendum); hence neither is it known whether there would be any justifiable criticism of even the darkest coloured refrozen fish. The off-white colour encountered in the present investigations was much more prevalent in fillets of fish frozen at sea than in those frozen from landed, iced fish. It is suspected that inhibition of the bleeding process can contribute to the problem, thus the recommendation is made that strict attention be paid to effective bleeding and gutting prior to freezing at sea.

Thawed cod were found to absorb salt more readily than unfrozen fresh fish. This fact will influence the choice of water for thawing and for holding the thawed fish and the choice of fillet-conveying systems.

Since full thawing in the dielectric thawer resulted in some overheated fish, the conveyorized water thawer operating at 18° to 22°C (65° to 72°F) and the dielectric thawer could be compared on equal terms only when the cod and flounder were partly thawed. Partial thawing using the dielectric or the water methods could not be distinguished in terms of effect at filleting or after refrozen storage

Within each of the three species refrozen stored samples, previously thawed in *sea-water* following partial thawing in the dielectric thawer or completely thawed in the dielectric thawer (overheated samples not included in the assessment), were given almost similar texture (taste panel assessment) ratings. The production from the combination dielectric–sea-water thaw developed salty tastes, these being accepted happily by the panel in the redfish but not so in the cod and flounder. Substitution of tap water for sea-water for completing the thaw resulted in similar sensory evaluation of the production from the dielectric and combination methods.

The refrozen stored packs prepared from cod thawed in humidified air and in water were similar as judged by chemical means. There was no significant leaching of protein in either case.

Holding cod 12 and 16 h and flounder 16 and 48 h in ice after partial thawing did not affect texture or taste scores of refrozen fillets.

Influence de la décongélation et des méthodes de décongélation sur la conservabilité du poisson (immédiate et après recongélation)

La communication traite des questions suivantes:

(1) Aspect, caractéristiques et utilisation, après décongélation, de la morue (*Gadus morhua*), de la plie américaine (*Hippoglossoides platessoides*) et de la rascasse du Nord (*Sebastes marinus mentella*) congelées à bord de chalutiers.

(2) Effets comparés des méthodes de décongélation sur l'évaluation sensorielle, organoleptique et chimique du poisson avant et après la seconde congélation et l'entreposage en chambre froide.

(3) Influence du milieu dans lequel se trouve le poisson décongelé durant l'entreposage sous réfrigération avant la seconde congélation.

(4) Pertes de poids survenant durant la décongélation ou pendant l'entreposage à environ 0°C après la décongélation.

Aucun des poissons énumérés, s'ils sont congelés en mer à l'état frais, ne donne à la décongélation d'odeur dénotant une altération.

Après décongélation, la morue éviscérée et étêtée peut manifester un léger brunissement à la surface de sectionnement. Ce phénomème peut influer sur le rendement au filetage, mais n'affecte pas la qualité du poisson décongelé ou recongelé. La congélation en mer de la morue non étêtée améliorerait l'aspect du poisson décongelé apprêté pour la vente "en frais".

Les filets obtenus après décongélation à partir de morues étêtées et de plies éviscérées peuvent être de couleur plus sombre (tirant légèrement sur le vert) que ceux qui proviennent de poissons débarqués sous glace. Rien n'indique que la chair ainsi colorée possède des caractéristiques différentes des filets "blancs" du point de vue du goût ou de la texture. Lorsqu'elle apparaît dans les filets de poisson décongelé (plie), cette coloration persiste en chambre froide de conservation. On ignore si le léger verdissement du poisson entreposé en chambre froide est plus prononcé que celui qui s'est manifesté dans des filets congelés préparés à partir de poissons mis sous glace en mer (voir Additif); aussi ignore-t-on également si même le poisson recongelé de couleur plus foncée peut donner prise à la critique. La coloration verdâtre relevée durant la présente étude était beaucoup plus marquée dans les filets de poisson congelé en mer que dans les filets congelés obtenus à partir de poissons débarqués sous glace. On pense que l'inhibition de l'écoulement du sang peut être un facteur, et l'on recommande donc de veiller attentivement à ce que le poisson soit bien saigné et éviscéré avant sa congélation en mer.

On a constaté que la morue décongelée absorbait davantage le sel que le poisson frais non congelé. Il faudra en tenir compte dans le choix de l'eau servant à la décongélation ou dans laquelle sera tenu le poisson décongelé, ainsi que dans celui du système de transport des filets.

Etant donné que la décongélation complète dans l'appareil diélectrique a produit dans certains cas un surchauffement du poisson, il n'est possible de comparer équitablement le décongélateur à convoyeurs fonctionnant à l'eau et à une température de 18° à 22°C (65° à 72°F) et le décongélateur diélectrique que lorsque la morue et la plie sont partiellement décongelées. Il n'a pas été possible d'établir de différence entre la méthode diélectrique et la méthode hydrique pour la décongélation partielle du point de vue de l'influence sur le filetage ou après entreposage de produits recongelés.

Pour chacune des trois espèces, des échantillons stockés après recongélation, et auparavant décongelés dans de l'*eau de mer* après décongélation partielle dans l'appareil diélectrique ou complètement décongelés dans ce dernier (les échantillons surchauffés ayant été exclus de l'évaluation), ont reçu des notes à peu près identiques pour ce qui est de la texture (jury de dégustation). Les produits obtenus

en combinant la décongélation diélectrique et la décongélation à l'eau de mer avaient un goût salé, bien accueilli par les membres de l'équipe de dégustation pour la rascasse du Nord, mais non pour la morue ou la plie. Le remplacement de l'eau de mer par de l'eau douce pour parfaire la décongélation a donné des résultats analogues du point de vue de l'évaluation organoleptique des produits de la méthode diélectrique et de la méthode mixte.

Les blocs préparés à partir de morue décongelée dans de l'air humidifié et dans de l'eau et entreposés après recongélation ont été jugés identiques d'après les méthodes chimiques. Dans aucun des deux cas n'a été constaté de lessivage important de protéines.

Le maintien de la morue pendant 12 et 16 heures et de la plie pendant 16 et 48 heures sous glace après décongélation partielle n'a pas influé sur l'appréciation des filets recongelés des points de vue de la texture ou du goût.

Influencia de la descongelación y de los métodos de ésta sobre la calidad de almacenamiento del pescado antes y después de recongelado

Este informe trata de:

(1) El aspecto, características y utilizaciones del bacalao (*Gadus morhua*) congelado en el barco, la platija americana (*Hippoglossoides platessoides*) y la gallineta (*Sebastes marinus mentella*) después de la descongelación.

(2) Los efectos comparados de los métodos de descongelación sobre la evaluación sensorial, organoléptica y química del pescado antes y después de la segunda congelación y almacenamiento frigorífico.

(3) La influencia de la conservación en bodegas y de los elementos existentes en ellas durante el almacenamiento refrigerado previo a la segunda congelación.

(4) Las pérdidas de peso que se verifican en la descongelación o durante la conservación en las bodegas después de la descongelación a 0°C aproximadamente.

Ninguno de estos peces, si se congelan frescos en el mar, presenta mal olor al descongelarse.

Al ser descongelado, es posible que el bacalao eviscerado y descabezado pueda adquirir un color oscuro en las superficies del corte. Este aspecto puede afectar a los rendimientos al filetearlo pero no influye en la calidad del pescado no congelado o vuelto a congelar. La congelación del pescado entero efectuada en el mar mejoraría el aspecto del bacalao descongelado "limpio" destinado a la venta como "fresco".

Los filetes obtenidos del bacalao descabezado y de las platijas evisceradas después de la descongelación pueden adquirir un color más oscuro (que tiende a ser de un tono verde) que los filetes preparados con el pescado desembarcado con hielo. No hubo pruebas de que el pescado de color blanco sucio poseyera un sabor distinto o características de textura diferentes a los de los filetes normalmente "blancos". Sin embargo, el color persistía en el almacenamiento frigorífico si aquél existía en los filetes (platija) del pescado descongelado. Se ignora si el color del pescado almacenado en frío era más pronunciado que el que se encontró en algún pescado congelado preparado a base de los desembarques con hielo (véase Addendum); de aquí que tampoco se sepa si estaría justificado poner objecciones al pescado vuelto a congelar de color todavía más obscuro. El color blanco oscuro que se ha encontrado en las actuales investigaciones prevalecía mucho más en los filetes de pescado congelado en el mar que en los congelados del pescado desembarcado con hielo. Se supone que la inhibición del proceso de sangrado puede contribuir a este problema, recomendándose por esto que se preste mucha atención a un buen sangrado y eviscerado antes de efectuar la congelación en el mar.

Se observó que el bacalao descongelado absorbe sal con mucha más facilidad que el pescado fresco no congelado. Este hecho influirá en la elección del agua utilizada para la descongelación y para la conservación del pescado descongelado, así como en la elección de los sistemas de transporte de los filetes.

Como la descongelación completa en el descongelador dieléctrico dio lugar a que el pescado se calentara excesivamente, el descongelador de agua corriente operando de 18° a 22°C (65° a 72°F) y el descongelador dieléctrico se podrían comparar en iguales términos únicamente cuando el bacalao y las platijas se descongelaron parcialmente. La descongelación parcial efectuada con los dos métodos no se podría distinguir en términos de eficacia al filetearse o después del almacenamiento del pescado vuelto a congelar.

A cada una de las muestras de las tres especies almacenadas y vueltas a refrigerar, descongeladas previamente en *agua de mar* después de una descongelación parcial en el descongelador dieléctrico o completamente descongeladas en éste (las muestras sobrecalentadas no se incluyeron en la determinación), se les dieron clasificaciones de textura casi similares (según la opinión del equipo de catadores). La producción de la combinación descongelador dieléctrico—agua de mar dio lugar a sabores salados, siendo éstos aceptados favorablemente por el equipo de catadores en lo que respecta a la gallineta pero no con respecto al bacalao y la platija. La sustitución del agua corriente por agua de mar para completar la descongelación dio lugar a una evaluación sensorial semejante de la producción a partir de los métodos de combinación y dieléctricos.

Los productos almacenados de bacalao recongelado obtenidos del pescado descongelado en aire humedecido y en agua fueron similares cuando se evaluaron por medios químicos. No existió pérdida importante de proteínas por lixiviación en ningún caso.

La conservación del bacalao en hielo durante 12 y 16 horas y de la platija durante 16 y 48 horas después de la descongelación parcial no influyó en la puntuación correspondiente a la textura o al sabor de los filetes vueltos a congelar.

THE physics and engineering involved in thawing block-frozen groundfish by several methods have been investigated. Commercial dielectric (Jason and Sanders, 1962a, 1962b), humidified air (Anon., 1964), water spray (Anon., 1967a) and conveyorized water thawers (Anon., 1967b; MacCallum and Sepic, 1967), have been tested. In addition, papers have been presented by the present authors and others showing the general acceptability of processed, twice-frozen stored fillets prepared from fish thawed ashore. However, there is little published data available on the commercial performance of the various thawers and, with the exception of work by MacCallum *et al.* (1967a), Peters *et al.* (1968) and Lorentzen and Pettersen (1966) on the relative effect of particular thawing and ancillary operations on the appearance, texture and odours of thawed fish and on the chemical and organoleptic qualities after refreezing and storing. The present authors discuss the effects of air-, dielectric- and water-thawing and combination dielectric and water operations carried out on a plant scale or on smaller lots as well as the effects of various types of chill storage between thawing and reprocessing. The authors are very pleased to acknowledge the valuable assistance received from industry in the prosecution of these studies. Use was made of freezer trawlers and of the production from commercial freezing, thawing and processing plants. There was considerable exchange of data between plant quality control and production personnel and research workers for study purposes, particularly those dealing with results obtained from industry and laboratory taste panels. This co-operation has permitted drawing meaningful conclusions from the work.

METHODS

Laboratory procedures and assessment

Where applicable, these followed the description given by the present and other authors in two previous publications (MacCallum *et al.*, 1967b, 1968). Moisture was determined by drying 15 to 20 g samples at 105°C (220°F) for 24 h, total nitrogen (TN) by the Kjeldahl–Gunning Arnold method (Jacobs, 1959) using 4 to 5 g samples, non-protein nitrogen (NPN) by the method of Campbell and Hanna (1937) on a filtrate obtained from a 25 g sample extracted using trichloroacetic acid of a final concentration of 5 per cent.

Skinned fillets of thawed cod and flounder and of iced-at-sea controls (flounder only) were examined by a five-member panel comprised of industry and research laboratory personnel. The fillets were assessed for appearance, odour and texture and each attribute rated on a five-point scale ranging from 5 for excellent quality to 1 for poor quality (Peters *et al.*, 1968). As an example of the scoring by the panel very fresh fish iced on the Grand Bank and landed in St. John's may be graded about 4 but on the average scores run between 3 and 4, a score of 3 being "good". It should be emphasized that the absolute score given thawed or control fillets could vary among panels.

Handling

Methods including treatment of fillets in sodium tripolyphosphate (TPP) followed the description given by the present and other authors in two publications (MacCallum *et al.*, 1967b, 1968) referred to above; otherwise treatments are indicated herewith. Reference to the use of specific commercial thawing equipment (Anon., 1967b) is also made.

RESULTS AND DISCUSSION

Appearance, characteristics and uses of thawed fish

The two major forms envisioned for marketing trawled fish frozen whole, whole and eviscerated, or "dressed" on board Canadian and U.S. vessels are refrozen fillets, portions or blocks and "fresh" fish. The frozen whole or dressed fish would be thawed ashore. Those marked "fresh" in the dressed or filleted state would be iced or otherwise chilled after thawing. For refreezing, fillets would be either skinned or packed skins on and would be trimmed and deboned as required for the particular market.

An earlier report (MacCallum *et al.*, 1967b) showed any effect on the texture of cod (*Gadus morhua*), flounder (*Hippoglossoides platessoides*) and redfish (*Sebastes marinus mentella*) of thawing, refreezing and storage to be minor. Therefore, it is unlikely that it will be possible to distinguish between single- or double-frozen processed fish at the eating stage. Further discussion on quality in this paper will not stress the significance of the thawing and refreezing operations as such but will be confined to areas not heretofore examined fully, namely (1) particular physical characteristics at thawing which might affect the marketability of the unfrozen fish or its value for processing and refreezing and (2) differences (if any) which may arise from differences in thawing and post-thawing treatment.

Cod, flounder and redfish, if freshly frozen at sea, carry no spoilage odours on thawing, an important point if marketed in competition with iced fish.

It is noteworthy that Poland (Tapiador and Carroz, 1963) permits some slight lessening of the standards for firmness in thawed fish as compared with fresh fish, admitting a weakening of flesh consistency due to freezing. There is some loss in resiliency in cod muscle upon thawing. However, this is not a serious matter if the fish are not abused during processing. Flounder and redfish, if freshly frozen, are firm and have good resiliency on thawing. In general, they are equal to or better than fish of iced landings in exterior appearance and in texture.

After thawing, it was observed (see page 220) that eviscerated cod, stored for 20 h in sea-water at 0°C (32°F) absorbed about 0.5 per cent salt whereas unfrozen fresh fish, stored for a similar time in chilled sea-water absorbed less than 0.1 per cent (MacCallum and Chan, 1961). This difference is attributed in part to softening, e.g. separation of the flakes or myotomes of the flesh as the result of thawing. Softening during thawing and later during filleting is believed responsible for the physical entrainment of sea-water in which cod fillets (removed from fish thawed in fresh tap water) were flumed. Tasting showed the fillets to be quite salty after fluming for only a few minutes. Thus, this method of conveyance is not recommended.

Any softening in thawed cod used in freeze-thaw-refreeze operations is of interest to the processor primarily and not the housewife. In this connection the authors are able to report in a preliminary way on some points of interest.

The ability of thawed fish to stand up to the knife at filleting (affecting yields of either the unfrozen or refrozen pack) depends to a great extent on the temperature to which the fish is raised during thawing. Best results are obtained in fish barely thawed near the backbone; on the other hand, too much frost in this area makes it difficult for the filleter to remove the fillet complete.

Weights were recorded before and after partially thawing 258 45-kg (100-lb) blocks (each measuring about $107 \times 51 \times 10$ cm) of frozen eviscerated headed market cod (small) frozen aboard ship in July 1966. The fish, potentially soft at killing, lost 1.5 per cent of the frozen weight after partial thawing for $2\frac{1}{2}$ h in tap water at 20°C (68°F) in a large [18 m (60 ft) long] conveyorized commercial thawer installed at Catalina, Newfoundland. About 8,600 kg (19,000 lb) of the partially-thawed fish lost an additional 1.4 per cent weight after overnight storage in ice. Still another lot of cod [4,400 kg (9,600 lb)] from the same cargo, almost completely thawed after $3\frac{3}{4}$ h immersion in water at 18°C (65°F), lost 0.6 per cent weight during similar storage in ice.

Notwithstanding the good texture on thawing, the weight of heads-on, gutted flounder, after thawing in water or dielectrically, will be less than that of the frozen blocks. This could be due to entrainment of ice in the blocks, and to the loss of extremities during handling the brittle fish. Losses ranging from 1.4 to 3.6 per cent were measured in thawing upwards of 500 44-kg (97-lb) blocks of flounder under the conditions described for the cod. As with cod, there is evidence of weight loss in chill storage after thawing.

Research workers have given much thought to the effect of handling on the development of softness in sea-frozen fish. It is generally thought that such softness on thawing should be minimized by adhering to sensible schedules for freezing at sea. Banks (1962) noted that thawed cod, in the raw state, can be softer than fresh cod but states that required firmness can be obtained in the material if storage in ice, prior to freezing at sea, is limited to three days. Peters *et al.* (1968) rated the

texture and appearance of fillets of thawed *pre-rigor* frozen cod considerably higher than that of fillets prepared from thawed, *post-rigor* (three days in ice) frozen fish. Present commercial operations for freezing dressed fish at sea appear to emphasize freezing the catch on the day of capture.

It will be seen from the above that it would be preferable to channel only the firmest of thawed cod (and this will not include material held longer than three days prior to first freezing) into "fresh" sales in competition with iced fish, and to use any softer fish for refreezing.

We have found that dressed cod, frozen at sea, lose much of their slime during water thawing at 15° to 20°C (60° to 68°F), accumulations of slime rising to the surface of the water and floating off to drainage. Because of the loss of slime the fish have less "bloom" immediately upon thawing than do iced fish. This loss of "bloom" should not be construed as loss of freshness. On the other hand, flounder and redfish have excellent "bloom" on thawing. The skin pigmentation of whole, ungutted redfish, thawed in water at 15.5°C (60°F) is superior to that of dielectrically-thawed fish which in turn is superior to that of most iced landings. All thawed redfish and flounder, freshly frozen at sea and examined by us, appeared highly suitable for presentation to the filleter.

Upon thawing, gutted, headed cod may be discoloured (brown) at the cut surfaces. It would probably help the sale of thawed dressed cod if the fish were effectively bled and gutted but not headed before freezing at sea, leaving the heading operation to be carried out by the shore processor following thawing. This will ensure white flesh at the neck without sacrificing yield.

The fillets of thawed cod can be darker than those of iced landings. Off-whiteness can tend to a green hue. However, organoleptic assessment (this page) of the refrozen stored samples which had not been culled for off-whiteness showed the fillets to be of quite uniform quality with respect to both taste and texture. We have no experience with the marketing of the fillets "fresh", hence those producing for "fresh" sales should be alerted to the possibility of critical comparison with fillets of fish from iced landings. British success in marketing fillets of thawed cod on a large scale should be noted as well as the fact that most of the production in that country goes to the fish fryers.

Off-white colour (tending to a green hue) in some water- or dielectrically-thawed flounder, commented on by MacCallum *et al.* (1967b), appears to have no effect on the taste upon cooking "fresh" or after refrozen storage. The discolouration persisted in frozen storage if present in fillets (flounder) of thawed fish. It is not known whether the colour in the cold-stored pack was more pronounced than encountered in some frozen fish prepared from iced-at-sea landings (*see* Addendum); hence neither is it known whether there would be any justifiable criticism of even the darkest coloured refrozen fish. The off-white colour encountered in the present investigations was much more prevalent in fillets of fish frozen at sea than in those frozen from landed, iced fish. It is suspected that inhibition of the bleeding process can contribute to the problem, thus the recommendation is made that strict attention be paid to effective bleeding and gutting prior to freezing at sea.

Influence of thawing methods on quality

Water and dielectrically-thawed cod. In earlier studies (MacCallum *et al.*, 1967a) on the effect of various thawing methods on the quality of refrozen stored fillets, it was shown that a controlled temperature of 15.5°C (60°F) during thawing in tap water had no deleterious effect over a temperature of 7.2°C (45°F). In more recent studies the temperature of the water in the conveyorized commercial water thawer was controlled at still higher temperatures with the results reported below. One hundred and eighty blocks of small market cod, trawled near shore in July, frozen *pre-rigor* aboard ship and stored at −23°C (−10°F) for one month, were partially thawed in 20°C (68°F) tap water in 2½ h while another lot of 90 blocks of the same landing was very nearly completely thawed in 18°C (65°F) tap water in 3¾ h. The warmest portions of any fish measured were about 15°C (59°F), the coldest about −1°C (30°F). Both lots of fish, subjected throughout to the vicissitudes of a commercial operation, were stored in ice overnight in a room at 9°C (48°F) and were uniformly lowered to a temperature close to 0°C (32°F). During commercial processing next day skinned fillets, not preselected for colour, were chosen at random and treated with sodium tripolyphosphate (TPP) as described by MacCallum *et al.* (1967b), packed in 1-lb (454-g) cartons, wrapped in Saran, frozen in 1 h and stored at −23°C (−10°F) for taste panel examination. Other fillets removed from the processing line before TPP-treatment were examined by a five-member panel as described under "Methods".

Forty-five blocks of cod of the same landing described above were thawed under reduced power in water-filled plastic trays conveyed through a commercial 120 kW, six-generator dielectric thawer (38 Mc/s) in about 1 h. Some fish were overheated, many more underheated and a few (about 7 per cent) were ready for filleting. The latter were filleted and the fillets examined, treated, packed and frozen for taste panel evaluation as described above. The remainder of the fish, excluding the overheated samples, were iced to permit completion of thawing and were processed next day. They are reported on immediately below.

The results of sensory evaluation of thawed fish are given in table 1. The panelists gave the water-thawed (items 1 and 2) and dielectrically-thawed (items 3 and 4) cod similar ratings, between "good" and "very good" for appearance, texture and odour.

Some of the fish were judged to have mild "cardboardy" odours which contributed to the scores reported. Such odours are not attributed to the high temperature of the thawing medium [for they were noted too in other cod (see page 220) thawed in 13°C (56°F) water] but possibly to mild (and organoleptically unimportant) oxidation of the lipid. It is believed by Castell (MacCallum *et al.*, 1967b) that detection is possible only because these fish carry no odours resulting from bacterial spoilage.

The free drip in these fish was high (in relation to unfrozen trap fish, MacCallum *et al.*, 1968) and the moisture slightly high (Dyer and Dingle, 1961).

The results of organoleptic and chemical evaluation of the frozen samples are given in Table 2. The water-thawed refrozen fish, examined six and 30 weeks after

TABLE 1. SENSORY* AND CHEMICAL EVALUATION OF FILLETS OF SMALL MARKET SIZE GRAND BANK TRAWLED COD FROZEN AT SEA BEFORE RIGOR IN JULY 1966

Item No.	Date of thawing 1966	Method of thawing	Time in ice after thawing unprocessed fish (h)	Fillet Appearance†	Fillet Texture†	Fillet Odour†	Moisture (% wet wt)	Free drip (% wet wt)
1	24th August	Partially thawed in a conveyorized water thawer for 2½ h at 20°C (68°F)‡	16	3.6 ±0.03	3.2 ±0.12	3.1 ±0.10	82.7§	6.5‖
2	29th August	Almost completely thawed in a conveyorized water thawer for 3¾ h at 18°C (65°F)	16	3.0 ±0.08	3.1 ±0.06	3.5 ±0.10	82.5§	8.6‖
3	12th August	Partially thawed in water-filled plastic trays in a commercial di-electric thawer under reduced power for 1 to 1¼ h	16	3.3 ±0.15	2.7 ±0.13	3.6 ±0.07	82.4§	9.9¶
4	12th August		16	3.0 ±0.15	3.2 ±0.12	3.5 ±0.09	84.1§	7.6‖
5	12th August		0	2.8 ±0.12	2.4 ±0.10	3.2 ±0.20	81.9§	7.8‖

* Evaluation was based on 5, excellent; 4, very good; 3, good; 2, fair; 1, poor.
† Each score represents the average of six fillets, each fillet evaluated by a five-member panel ($n = 30$).
‡ Note that the temperature is appreciably higher than investigated and reported on previously [7.2° and 15.5°C (45° and 60°F)], MacCallum *et al.* (1967a).
§ Duplicate samples from each of two fillets chosen randomly from among the six assessed organoleptically, results averaged.
‖ One sample from each of the four fillets remaining from §, results averaged.
¶ One sample from each of two fillets remaining from §, results averaged.

capture (items 1 and 2) were given similar texture ratings, these being as high as those for February Grand Bank cod frozen *pre-rigor* at sea, thawed in cooler water [at 13°C (56°F)], filleted immediately, TPP-treated, refrozen and examined after storage at −20°C (−5°F) for 22 weeks (table 6, line 2). The taste scores of the present refrozen cod samples were somewhat low but acceptable, the panelists perceiving some staleness starting as early as six weeks and considerably more at 30 weeks. The chemical indices of texture and flavour did not change with storage. The quality of the fish from the start was low as judged by salt extractable protein. However, we have record of such values in another log of Bank fish examined, an October 1964 catch (MacCallum *et al.*, 1966), in which both once- and twice-frozen fish had an average extractable protein nitrogen (EPN) value of 1.19 after 30 weeks' storage.

There is nothing in the organoleptic and chemical data to indicate differences in water- and dielectrically-thawed fish.

It is concluded therefore that the water- and dielectric-thawing processes could not be distinguished in terms of effect on the thawed fish or on the refrozen stored pack of this initially rather poor lot of fish. These results agree with earlier findings on water- and dielectrically-thawed and refrozen cod and redfish (MacCallum *et al.*, 1967a).

Water and dielectrically-thawed flounder. Heads-on, eviscerated flounder [258 blocks, weighing 11,000 kg (25,000 lb)] frozen *pre-rigor* on the Grand Bank in July 1966, were partially thawed commercially [immersed for 2½ h in 22°C (72°F) tap water] about one month later, stored overnight in ice, processed, examined, TPP-treated and frozen as described for cod. Another lot (90 blocks) of the same flounder provide data on fish which underwent longer exposure on thawing [over 3 h at 19°C (66°F)] and prolonged storage in ice (two days). Also, on three occasions (30, 38 and 138-block lots) flounder from the same landing were thawed under reduced power in the commercial dielectric thawer under conditions (see page 216) described for cod. Some fish were overheated, many more underheated and some (about 15 per cent of the total) were ready for immediate filleting. The filletable fish were examined organoleptically, processed, TPP-treated and refrozen for later reporting (see page 220). The stiff fish which were not

TABLE 2. CHEMICAL AND ORGANOLEPTIC ASSESSMENT OF REFROZEN, TPP-TREATED FILLETS OF SMALL MARKET SIZE GRAND BANK TRAWLED COD FROZEN AT SEA BEFORE RIGOR IN JULY 1966

Item* No.	Date of thawing 1966	Time in ice after thawing unprocessed fish (h)	Weeks in cold storage at −23°C (−10°F) after refreezing	Texture†	Taste†	Moisture (% wet wt)	Thaw-drip (% wet wt)	Total lipid§ (% wet wt)	FFA§ (% total lipid)	EPN (% wet wt)
1	24th August	16	6	63±1.98 (22)	62±2.42 (22)	82.5‖	17.3‖	0.83	26.8	1.38‡
			30	61±2.57 (18)	51±2.97 (18)	81.6‡	14.9‡	0.81	31.3	1.36§
2	29th August	16	6	56±1.86 (24)	53±2.31 (24)	82.7‖	15.3‖	0.81	37.3	1.26‡
			30	59±1.93 (18)	44±3.13 (18)	81.8‡	12.4‡	0.81	37.8	1.13§
3	12th August	16	6	63±1.78 (23)	64±2.87 (23)	82.8‖	14.0‖	1.01	27.3	1.52‡
			30	60±2.44 (18)	49±2.44 (18)	82.1‡	16.3‡	0.81	36.9	1.42§
4	12th August	16	6	61±2.25 (24)	59±2.15 (24)	82.3‖	15.3‖	0.71	32.9	1.67‡
			30	58±2.31 (18)	46±2.90 (18)	81.8‡	10.5‡	0.60	38.8	1.03§
5	12th August	0	6	63±1.68 (23)	61±2.05 (23)	81.3‖	8.9‖	0.77	35.6	1.64‡
			30	60±2.08 (18	48±2.36 (18)	81.5‡	5.2‡	0.75	38.4	1.29§

* *See* same item table 1 for method of thawing.
† Taste and texture scores are followed by the standard error of the mean and by the number of judgments (in parentheses).
‡ Duplicate random sampling of each of two 1-lb (454-g) packages of several fillets, results averaged.
§ Single random sampling of each of two 1-lb (454-g) packages of several fillets, results averaged.
‖ Duplicate random sampling of one 1-lb (454-g) package of several fillets, results averaged.

overheated, reported on immediately below, were iced overnight and processed, TPP-treated and refrozen. Other flounder, iced at sea and landed unfrozen three days later, were used for random selection of controls for sensory evaluation.

The results of sensory evaluation of thawed fish are given in table 3. The skinned control fillets were yellowish-brown in the layers of fat under the skin on both the back and belly sides but otherwise were mainly of white colour. The skinned fillets of both dielectrically- and water-thawed fish which were of appearance similar to the unfrozen controls were separated for inspection purposes from thawed fillets of off-white (tending to a green hue) colour. Irrespective of the method of thawing, the white-coloured fillets of thawed fish iced overnight were given a "very good" grade for appearance, odour and texture (exception, item 7) equal to iced-at-sea controls (see footnote ‡, table 3), the off-white a "fair" to "good" rating for appearance and a grade between "good" and "very good" for texture and odour.

The two groups of fillets prepared from water-thawed fish iced for two days (items 3 and 4) were poorer in appearance, texture and odour upon filleting than were the samples iced overnight (items 1 and 2) but still averaged a "good" rating. As noted immediately below the two-day iced fish were not inferior as judged by organoleptic assessment following refreezing.

There was considerable variation in moisture content (items 1–8), some of which would be expected because of a variation in the lipid content of flounder (MacCallum *et al.*, 1967b).

The results of organoleptic and chemical evaluation of the frozen samples are given in table 4. The dielectrically-thawed iced fish (items 5–8), whether white or off-white in colour, had thiobarbituric acid (TBA) values equal to or greater than those for the off-white, water-thawed fish (item 2). The off-white colour noted in the fillets of some thawed flounder persisted during refrozen storage. There was little evidence of green colour in any of the frozen control fillets.

With the exception of the fish iced for two days (items 3 and 4) the panel tended to find great difficulty in assessing the flounder for taste in the presence of the flavour imparted by the sodium tripolyphosphate. As a result, scores for taste are conceivably somewhat low in terms of actual quality. The panel did not differentiate in taste or texture between the off-white and white-coloured fillets of iced fish thawed by the two methods

TABLE 3. SENSORY* AND CHEMICAL EVALUATION OF FILLETS OF 1 TO 1.5 KG (2 TO 3 LB) GRAND BANK TRAWLED FLOUNDER FROZEN AT SEA BEFORE RIGOR IN JULY 1966

Item No.	Date of thawing whole fish 1966	Method of thawing	Time whole thawed fish in ice before filleting (h)	Colour in fish fillets	Number of observations in each assessment category	Organoleptic assessment			Laboratory measurements	
						Appearance†	Texture†	Odour†	Moisture (% wet wt)	Free drip (% wet wt)
1	22nd August	Thawed for 2½ h at 22°C (72°F) in a conveyorized water thawer	16	White	21	4.2 ± 0.10	4.0 ± 0.18	4.0 ± 0.18	83.2‡	7.4¶
2	22nd August		16	Off-white	21	2.6 ± 0.19	3.0 ± 0.22	3.6 ± 0.23	80.7‡	8.1¶
3	20th August	Thawed for 3 h at 19°C (66°F) in a conveyorized water thawer	48	White	15	3.6 ± 0.20	3.5 ± 0.19	3.3 ± 0.15	80.5‡	5.5¶
4	20th August		48	Off-white	15	2.4 ± 0.13	3.0 ± 0.20	3.1 ± 0.21	81.5‡	8.4¶
5	12th August	Thawed for 1 to 1½ h in water-filled trays in a commercial dielectric thawer operated at reduced power	16	White	18	4.9 ± 0.05	4.9 ± 0.05	4.3 ± 0.13	82.7‡	6.0¶
6	12th August		16	Off-white	18	2.8 ± 0.12	4.0 ± 0.16	3.4 ± 0.13	83.6‡	12.0¶
7	25th August		16	White	48	4.0 ± 0.09	3.7 ± 0.09	3.8 ± 0.09	80.9§	8.7**
8	25th August		16	Off-white	48	2.7 ± 0.09	3.1 ± 0.08	3.0 ± 0.09	80.9§	7.7**
9	11th August		0	White	24	4.7 ± 0.09	4.4 ± 0.10	4.2 ± 0.15	81.9‖	9.4¶
10	11th August		0	Off-white	28	4.1 ± 0.06	4.7 ± 0.07	4.0 ± 0.16	80.3‖	8.4¶

* Evaluation was based on 5, excellent; 4, very good; 3, good; 2, fair; 1, poor.
† These average scores may be compared with those for fillets of 16 control fish, iced at sea, landed after three days and filleted on the fourth day *post-mortem*. The controls score as follows: appearance, 4.3; texture, 4.2; odour, 3.8.
‡ Duplicate samples from one fillet chosen randomly from among those assessed organoleptically, results averaged.
§ Duplicate samples from each of eight fillets assessed organoleptically, results averaged.
‖ Duplicate samples from each of two fillets chosen randomly from among those assessed organoleptically, results averaged.
¶ One sample from each of two fillets selected randomly from those not assessed for moisture, results averaged.
** Free drip done on same fillets (one value per fillet) assessed in §, results averaged.

TABLE 4. CHEMICAL AND ORGANOLEPTIC ASSESSMENT OF REFROZEN FILLETS OF GRAND BANK TRAWLED FLOUNDER FROZEN PRE-RIGOR AT SEA IN JULY 1966

Item* No.	Date of thawing 1966	Time in ice after thawing unprocessed fish (h)	Colour in fish fillets	Weeks in cold storage at −23°C (−10°F) after refreezing	Texture†	Taste†	Moisture‡ (% wet wt)	Thaw-drip‡ (% wet wt)	Total lipid§ (% wet wt)	FFA§ (% total lipid)	EPN (% wet wt)	TBA‖ O.D. units
1	22nd August	16	White	6	68 ± 4.16 (23)	64 ± 2.21 (23)	79.8	19.8	2.89	9.89	1.62¶	0.040
				30	66 ± 1.62 (18)	36 ± 2.19 (18)	82.5	3.6	1.28	35.67	0.73‡	0.024
2	22nd August	16	Off-white	6	63 ± 2.62 (24)	58 ± 3.32 (24)	80.7	15.4	1.62	13.22	2.08¶	0.049
				30	62 ± 2.88 (17)	39 ± 2.85 (17)	81.0	9.9	1.97	18.78	1.89‡	0.078
3	20th August	48	White	30	64 ± 2.46 (17)	46 ± 2.90 (17)	—	—	—	—	—	—
4	20th August	48	Off-white	30	66 ± 2.16 (17)	49 ± 3.08 (17)	—	—	—	—	—	—
5	12th August	16	White	6	62 ± 2.54 (23)	54 ± 2.87 (23)	82.1	18.4	2.07	11.21	1.86¶	0.053
				30	63 ± 1.87 (18)	34 ± 2.53 (18)	82.3	16.2	1.87	16.97	1.47‡	0.168
6	12th August	16	Off-white	6	65 ± 1.94 (23)	68 ± 2.88 (23)	81.0	11.7	1.78	17.20	2.01¶	0.048
				30	63 ± 2.43 (18)	36 ± 2.37 (18)	82.3	9.7	2.66	12.79	1.70‡	0.117
7	25th August	16	White	30	58 ± 2.49 (18)	34 ± 2.01 (18)	81.0	11.3	2.26	15.72	1.57‡	0.081
8	25th August	16	Off-white	6	61 ± 2.64 (24)	60 ± 3.14 (24)	81.6	10.2	1.42	20.16	1.70¶	0.043
				30	64 ± 2.01 (18)	42 ± 3.29 (18)	80.0	11.2	1.27	23.04	1.96‡	0.077
9	11th August	0	White	6	62 ± 2.78 (23)	62 ± 2.72 (23)	81.7	10.8	0.88	20.73	1.89¶	0.017
				30	56 ± 3.18 (17)	50 ± 2.96 (17)	81.2	12.7	1.16	22.05	1.74‡	0.037
10	11th August	0	Off-white	6	63 ± 2.22 (22)	60 ± 3.49 (22)	81.4	9.9	1.38	17.07	1.87¶	0.025
				30	64 ± 1.44 (18)	32 ± 3.16 (18)	80.9	14.1	2.43	12.08	1.79‡	0.088

* See same item table 3 for method of thawing.
† Taste and texture scores are followed by the standard error of the mean and by the number of judgments (in parentheses).
‡ Duplicate random sampling of one 1-lb (454-g) package of several fillets, results averaged.
§ Single random sampling of two 1-lb (454-g) packages of several fillets, results averaged.
‖ Duplicate readings of single random sampling of one 1-lb (454-g) package.
¶ Duplicate random samplings of two 1-lb (454-g) packages of several fillets, results averaged.

(items 1–8). The texture averaged 64 at 10 and 30 weeks. The taste averaged a just acceptable 40 at 30 weeks, having dropped from 61 at first tasting.

Combination (dielectric plus sea-water or dielectric plus tap water) thawing. It was found possible to double production at the Catalina plant from that previously attained using the dielectric thawer alone by passing the frozen blocks quickly through the dielectric thawer and on to a water thawer where the operation was completed. It remained to examine the product of such combination thawing in comparison with material thawed completely in the dielectric thawer.

Several thousand pounds of cod, flounder and redfish, caught on or about 30th November 1964 on the Grand Bank and frozen *pre-rigor* aboard ship in 45-kg (100-lb) blocks were thawed ashore 10 days later, half of each species being defrosted for ½ h in tap water filled plastic trays in the dielectric thawer followed by thawing in sea-water at 13°C (56°F) for 37 min (flounder), 47 min (redfish) and 63 min (cod). The other half was dielectrically defrosted for nearly 1½ h under reduced power in the tap-water filled plastic trays. Overheated fish from the latter operation were segregated from properly thawed material. The latter were immediately filleted, skinned (cod and flounder only), TPP-treated (cod only), packed in 1-lb (454-g) cartons, frozen in 1 h and stored at −23°C (−10°F) as were the fish thawed by the combination method.

After 29 weeks (about the longest time that the Newfoundland processor is required to store frozen fish under "normal" marketing conditions) refrozen storage the texture of the combination-thawed cod, as assessed by the industry panel, was 60, lower by five points than that of the dielectrically-thawed fish and after 40 weeks 50, lower by 10 points than the latter. The former were inferior in taste by 5, 8, 10 and 20 points at 12, 19, 29 and 40 weeks respectively. The panel detected salty tastes in the combination-thawed fish. These developed a slightly bitter taste at 19 weeks.

There was no difference in texture scores for the flounder and redfish of the two thawings, these being about 80 at the first tasting, immediately after refreezing, and about 60 after 30 weeks refrozen storage. The panelists preferred the taste of the flounder thawed completely in the dielectric thawer. Initially, and up to 13 weeks storage, they preferred the salty taste of the combination-thawed redfish. The latter fish did not have the "oily" flavour of those thawed completely in the dielectric thawer. However, the difference in scores for fish of the two treatments dwindled until at 30 weeks taste scores were similar.

It is concluded therefore that completion of thawing in sea-water had minimal effect on refrozen texture of cod, flounder or redfish. The salty taste of the dielectric sea-water thawed samples was accepted happily in the redfish but was not pleasant in the cod and flounder.

Studies similar to the above, but confined only to sensory evaluation of the thawed fish, were carried out on several thousand pounds of cod and flounder frozen on the Grand Bank in July 1966 and thawed wholly in tap water at 19°C (66°F), wholly in the dielectric thawer under reduced power or combination-thawed dielectrically and in tap water (19°C, 66°F). After filleting there was no difference in appearance, texture or odour of the fish of the three treatments.

Humidified air and water thawing (table 5). A comparison was made between cod thawed in tap water at 15.5°C (60°F) and cod thawed in fully humidified air at 21°C (70°F) in order to determine whether the protein content of the fish was affected by the thawing method. One 45-kg (100-lb) block of headed eviscerated Grand Bank cod frozen *pre-rigor* at sea was divided into three parts. One part was water-thawed in 2½ h, the fish being separated during thawing, one air-thawed in about the same time and the other part retained to supply once-frozen controls. Chemical assessment showed no difference between controls and air- and water-thawed fish during 34 weeks' cold storage. From this we conclude that no significant leaching of protein can be expected when fish are thawed in warm, humidified air or by immersion in warm water under the controlled conditions described.

TABLE 5. CHEMICAL ASSESSMENT OF REFROZEN FILLETS AND ONCE-FROZEN WHOLE FISH PREPARED FROM THE SAME BLOCK OF HEADED EVISCERATED MARKET-SIZE GRAND BANK TRAWLED COD FROZEN AT SEA BEFORE RIGOR IN MAY 1965

Handling ashore	*Weeks in cold storage prior to analysing*	*Moisture (% wet wt)*	*Total lipid (% wet wt)*	*FFA (% total lipid)*	*Total nitrogen (% wet wt)*	*Non-protein nitrogen (% wet wt)*	*True protein* (% wet wt)*
Stored at −23°C (−10°F) as whole,	0	81.5†	0.83§	—	2.91†	—	—
headed, eviscerated fish	21	81.3‡	0.79‖	21.0‖	2.84‡	0.46‖	14.9
	34	82.3‡	0.65‖	19.9‖	2.73‡	0.45‖	14.3
Thawed in fully humidified air at 21°C	0	81.4†	0.86§	—	2.79†	—	—
(70°F), filleted, skinned, packed in 1-lb	21	81.9†	0.72§	31.4§	2.76†	0.45§	14.4
(454-g) cartons, refrozen and stored at	34	82.4‡	0.65‖	37.6‖	2.73‡	0.40‖	14.5
−23°C (−10°F)							
Thawed in tap water at 16°C (60°F),	0	81.4†	0.77§	—	2.87†	—	—
filleted, skinned, packed in 1-lb (454-g)	21	81.9†	0.77§	32.6§	2.67†	0.43§	14.0
cartons, refrozen and stored at −23°C	34	81.6‡	0.77‖	38.4‖	2.75‡	0.41‖	14.6
(−10°F)							

* True protein = (total nitrogen − non-protein nitrogen) × 6.25.
† Duplicate random sampling of each of three 1-lb (454-g) packages of several fillets, results averaged.
‡ Duplicate random sampling of each of two 1-lb (454-g) packages of several fillets, results averaged.
§ Single random sampling of each of three 1-lb (454-g) packages of several fillets, results averaged.
‖ Single random sampling of each of two 1-lb (454-g) packages of several fillets, results averaged.

Influence of chill holding after thawing

Cod. An experiment was conducted to compare the quality of refrozen cod iced 12 h after thawing with that of the immediately refrozen pack.

Blocks of cod frozen *pre-rigor* at sea and stored at about −26°C (−15°F) in the plant's cold storage for 2½ weeks were completely thawed in tap water at 13°C (56°F) for 3 h 20 min. Half the thawed fish were immediately filleted, skinned, TPP-treated, packed in 1-lb (454-g) cartons and refrozen in 1 h. The remaining dressed fish were iced for 12 h and then processed and treated in a similar fashion. Half the fillets were cold stored at about −26°C (−15°F) at the fish plant for five weeks, then removed to the only room then available to the laboratory in St. John's, one held at about −20°C (−4°F) where the fish were stored for another 22 weeks. The other half was stored at the fish plant at about −26°C (−15°F) for 44 weeks, then raised to about −20°C (−4°F) when transported to St. John's and was stored at this temperature for another two weeks prior to tasting.

Results of chemical and organoleptic assessment are given in table 6. After 46 weeks' storage, mainly at −26°C (−15°F), the quality of all the twice-frozen, TPP-treated cod was very good, as indicated by texture scores of 70 and EPN values of 2.05. Scores throughout the storage period were not affected by storage in ice prior to refreezing. However, the fish stored at −20°C (−4°F) for 22 weeks were graded significantly poorer than the lot stored for 44 weeks at −26°C (−15°F). Similar differences were found in EPN values as a result of storage temperature. Moisture content remained constant at about 81.9 for all fish regardless of handling. Thaw-drip values after five weeks' storage were highest in those fish processed immediately after thawing. This is contrary to results reported on dielectrically-thawed cod (see below). However, after 46 weeks' storage at −26°C. (−15°F) thaw-drip was greater in the present samples iced 12 h before processing and refreezing.

In other cod, thawed dielectrically under reduced power, processed, TPP-treated and frozen immediately after thawing (item 5, table 2), the moisture and thaw-drip at six weeks and the thaw-drip at 30 weeks were much lower than in the water- or dielectrically-thawed samples held in ice overnight (items 1–4). Holding in ice did not appear to affect texture or taste scores. As seen earlier it did contribute to weight losses prior to filleting.

Flounder. The number of off-white fillets appeared to be the same in fish examined immediately after partial thawing dielectrically under reduced power or after storage of the partially-thawed fish in ice overnight. Among the latter fish, those producing the whiter fillets were preferred as judged by the scoring for appearance of the fillets (table 3).

After the fillets had been cold stored for 30 weeks at −23°C (−10°F) the panel did not distinguish clearly between the taste or texture of those prepared from freshly frozen or delayed frozen white (items 5, 7, 9, table 4) and off-white (items 6, 8, 10, table 4) material or between white and off-white material handled similarly.

Effects of various types of chill storage between thawing and reprocessing (table 7)

Complete thawing of headed, eviscerated cod of 38- to 48-cm heads-off length, packed in 10-cm (4-in) thick blocks, is effected in about 2 h using the dielectric thawer and conveyorized water thawer in tandem. The same operation is effected in either water or in humidified air in about 4¼ h. Thus, to have fish ready for filleting at the start of the day's operation the thawers presently available to processing plants must be started up well ahead of the cutting room or thawed fish must be available from storage. Since the latter is often essential, work was done to provide information on the effects of different post-thawing holding on the immediate and cold storage quality of the refrozen pack.

Three blocks of dressed Grand Bank cod, each measuring 107×35×7.5 cm and weighing about 21 kg (47 lb), frozen *pre-rigor* at sea on 27th February 1965, were held at about −26°C (−15°F) for one month, then thawed in water at 13°C (56°F). Thawing was completed in 3 h 20 min. The fish in each block were separated into equal lots of three. One lot from each of the three blocks was stored for about 20 h in chilled fresh water, while three similarly chosen lots were stored in flaked ice and another three in chilled sea-water for 20 h, all storage temperatures being 0°C (32°F). The fish were then

TABLE 6. A COMPARISON OF TEXTURE SCORES* AND CHEMICAL ASSESSMENT OF TWICE-FROZEN, TPP-TREATED FILLETS OF GRAND BANK COD FROZEN PRE-RIGOR AT SEA AND PROCESSED IMMEDIATELY AFTER THAWING† OR AFTER THAWING AND STORAGE IN ICE (FOR 12 H)

Handling ashore	*Time (weeks) in cold storage at average temperature shown in brackets*	*Texture*	*pH*	*Moisture‡ (% wet wt)*	*Thaw-drip‡*	*EPN‡*
Processed immediately after thawing	5 [−26°C (−15°F)]	74±2.65 (21)	6.71‡	81.8	10.5	2.20
	5 [−26°C (−15°F)] + 22 [−20°C (−4°F)]	62±1.68 (34)	6.78§	81.9	9.3	1.48
	44 [−26°C (−15°F)] + 2 [−20°C (−4°F)]	70±1.97 (23)	6.88§	82.0	6.9	2.01
Processed after thawing and storage in ice	5 [−26°C]	74±2.60 (22)	6.85‡	82.0	6.5	2.16
	5 [−26°C] + 22 [−20°C]	59±1.33 (22)	6.84§	81.6	8.7	1.16
	44 [−26°C] + 2 [−20°C]	70±1.64 (24)	6.66§	81.9	10.7	2.09

* Texture scores are followed by the standard error of the mean and the number of judgments (in parentheses).
† Thawed two weeks after initial freezing in tap water at 14°C (57°F) for 3 h 20 min.
‡ Duplicate random sampling of two 1-lb (454-g) packages of several fillets, results averaged.
§ Single random sampling of two 1-lb (454-g) packages of several fillets, results averaged.

TABLE 7. TEXTURE SCORES* AND CHEMICAL ASSESSMENT OF TWICE-FROZEN FILLETS OF GRAND BANK COD HEADED EVISCERATED AND FROZEN PRE-RIGOR AT SEA, THAWED ONE MONTH LATER AND HELD IN THREE CHILL STORAGE MEDIA FOR 20 H BEFORE FILLETING AND REFREEZING

Chill 0°C (32°F) storage medium	Weeks refrozen in cold storage at −23°C (−10°F)	Texture	Moisture† (% wet wt)	Thaw-drip† (% wet wt)	Total lipid (% wet wt)	FFA‡ (% total lipid	TBA§ O.D. units	EPN† (% wet wt)	Salt (% wet wt)	Total nitrogen† (% wet wt)	Non-protein nitrogen‡ (% wet wt)	True protein‖ (% wet wt)	pH†
Ice	1	78±1.67 (24)	82.4	10.1	0.96	15.9	0.017	2.08	0.12¶	—	—	—	6.78
	26	56±2.36 (23)	81.8	11.0	0.69	32.2	0.021	1.38	0.11†	2.60	—	—	6.65
	39	56±3.04 (24)	82.2	6.3	0.75	37.8	0.026	1.50	0.09¶	2.61	0.35	14.1	6.69
Fresh water	1	75±1.91 (22)	82.7	8.9	0.72	27.6	0.015	2.05	0.11¶	—	—	—	6.83
	26	56±1.28 (23)	82.0	11.9	0.79	27.0	0.018	1.66	0.09†	2.70	—	—	6.85
	39	60±1.85 (24)	82.8	8.8	0.73	39.4	0.026	1.49	0.07¶	2.71	0.29	15.1	6.75
Natural sea water	1	73±1.53 (23)	82.1	10.5	1.15	13.7	0.016	1.98	0.63¶	—	—	—	6.58
	26	58±1.83 (24)	81.4	10.2	0.73	27.2	0.061	1.43	0.59†	2.79	—	—	6.60
	39	60±2.11 (24)	81.8	8.9	0.79	35.9	0.067	1.13	0.70¶	2.68	0.35	14.6	6.70

* Texture scores are followed by the standard error of the mean and by the number of judgments (in parentheses).
† Duplicate random sampling of two 1-lb (454-g) packages, each containing the fillets of one fish, results averaged.
‡ Single random sampling of two 1-lb (454-g) packages, each containing the fillets of one fish, results averaged.
§ Duplicate readings of single random sampling of each of two 1-lb (454-g) packages, each containing the fillets of one fish, results averaged.
‖ True protein = (total nitrogen − non-protein nitrogen) × 6.25.
¶ Duplicate random sampling of one 1-lb (454-g) package containing the fillets of one fish, results averaged.

washed in tap water, skinned, filleted and packed in 1-lb (454-g) waxed cartons (portions of the two fillets from each fish in its own carton) and plate frozen in 1 h. The refrozen fillets were stored at −23°C (−10°F).

All fish were quite firm at cutting and skinning and the fillets acceptably white. Some carried slight odours, described as mildly "cardboardy", but no spoilage odours were observed.

At initial tasting (one week after refreezing) all samples were given a good overall texture grade (table 7) ranging from 73 for those held in sea-water, 75 for the fish stored in fresh water and 78 for the iced fish. A salty taste was noted 23 out of 29 times for the fish held in sea-water and analyses showed that the fillets had absorbed about 0.5 per cent salt in pre-freezing handling.

After 25 and 38 weeks further storage samples were indistinguishable in texture, the grade being 56 to 61. All packs were slightly to medium chewy, fibrous and dry. Over this period of storage there was some depreciation in taste scores (incipient staleness) in samples of all treatments and the fish held in sea-water were again salty. The panel judged that the salty taste would be acceptable using cooking methods other than baking as in the home or after frying in fat as in the preparation of fish-sticks.

The moisture content of all samples at all three times analysed was always in the same range (81.4 to 82.8 per cent wet weight). The fish held in fresh water had the highest moisture, the iced fish next and the sea-water stored fish the lowest. The thaw-drip was in the same range (6.3 to 11.0 per cent wet weight) for all samples.

The total nitrogen (2.7 per cent of the fresh muscle weight) was the same independent of method of storage, being slightly lower than reported by Reay (1943) for Atlantic cod.

The extractable protein nitrogen was initially high for all samples (average 2.04 per cent fresh muscle weight). The lowest value was obtained from the sea-water stored fish. The values for the latter reached a low mark of 1.13 per cent after 38 weeks storage while values for the fish stored in ice and in fresh water were 1.50 per cent, indicating that the latter samples had undergone less denaturation.

At the commencement of cold storage the free fatty acids (FFA) seemed to be higher in the fresh-water stored fish but values for samples of all treatments were almost the same at 25 and 38 weeks amounting to 38 per cent of the total lipid at the latter time.

There was no evidence of developing rancidity in the fish held in ice or in fresh water as judged by the TBA values. However, for fish held in salt water, these values quadrupled during the first half of the cold storage period.

Thus, chemical tests and taste assessment showed that storage in chilled sea-water, following thawing, is the least desirable of the three methods investigated.

Acknowledgment

The authors gratefully acknowledge the co-operation of Mr. A. H. Monroe, President, Fishery Products Ltd., St. John's, Newfoundland, who made it possible to extend our research into actual fields of operation. They wish to thank Messrs. J. S. Crew and Fletcher Mayo of Fishery Products Ltd., and Miss Dorothy A. Chalker and Mr. George J. Biggs, Technological Unit staff for technical assistance in the preparation of some of the samples. The following persons contributed to both laboratory and taste panel phases of the work: Miss Dorothy A. Chalker, Messrs. George J. Biggs, David R. Adams, Bevin R. LeDrew, John T. Lauder, Mrs. Rosamund Gover and Mrs. June I. Jaffray. Mr. Fletcher Mayo was in charge of the industry taste panel. Mrs. June I. Jaffray and Miss Dorothy A. Chalker assisted in the organization of the material for publication.

ADDENDUM

Green discolouration in flounder

by H. C. Freeman and D. R. Idler

Green discolouration was observed in frozen fillets produced from "yellowtail" flounder (*Limanda ferruginea*) caught in the vicinity of Banquereau and landed by trawler as iced, round fish on 2nd November 1964. Most of the fish was cut following discharge and the remainder was held over and iced in chilled water tanks at −1° to 0°C (31° to 32°F) for a period of 19 to 30 h before processing. Age of the fish when cut was 4½ to 7 days. No objectionable odours or discolouration were noted at the time the fish were processed, but on storage a green discolouration was observed in some fillets.

Typical samples of these fillets were forwarded to this laboratory where Mr. C. H. Castell carried out tests and concluded that there was no evidence to connect the discolouration with bacteria.

Further studies were undertaken on tissue excised from the green areas of several fillets. The tissue was ground and extracted with ethanol. The ethanol-insoluble green colour was then extracted with chloroform. The chloroform was blown off at 40°C (104°F) using nitrogen and the oily residue, dissolved in *n*-hexane, was chromatographed on a methanol-deactivated silicic acid column. The lipids were removed by washing the column with *n*-hexane and the coloured material was separated into three distinct fractions by using methanol as developing solvent. The second band was found to have the same chromatographic mobility as standard bilirubin, which was run on a column under identical conditions. The Gmelin test was positive. The three coloured areas gave positive "phase tests" for the porphyrin group of compounds.

It is probable that the pigments were porphyrin degradation products derived from blood (haemoglobin) in the tissue. Bile pigments, or chlorophyll obtained from green plant matter in the fish intestine cannot be excluded as possibilities.

It was concluded that the green colour in flounder fillets, though undesirable in appearance, was harmless.

References

ANON. 1964 Ross thawing plant in full operation. *Fish Trades Gaz.*, No. 4203, 9–10.

ANON. 1967a Baader plant for thawing fish frozen at sea. *Fishg News int.*, **6**(1), 74, 76.

ANON. 1967b Trade views thawing demonstration. *Fisheries of Canada*, **19**(9), 7–8.

BANKS, A 1962 Identifying quality changes in frozen fish. *Annex 1962–1 Bull. int. Inst. Refrig.*, 445–451.

CAMPBELL, W R and HANNA, M I 1937 The determination of nitrogen by modified Kjeldahl methods. *J. biol. Chem.*, **119**, 1–7.

DYER, W J and DINGLE, J R 1961 Fish proteins with special reference to freezing. In *Fish as Food*, ed. G. Borgstrøm, Academic Press, New York, **1**, 275–327.

JACOBS, M B 1959 The chemical analysis of foods and food products, 3rd ed., D. Van Nostrand Company, Inc., New York, pp. 32–34.

JASON, A C and SANDERS, H R 1962a Dielectric thawing of fish. I. Experiments with frozen herrings. *Fd Technol., Champaign*, **16**(6), 101–106.

JASON, A C and SANDERS, H R 1962b Dielectric thawing of fish. II. Experiments with frozen white fish. *Ibid.*, **16**(6), 107–112.

LORENTZEN, G and PETTERSEN, R J 1966 The influence of the method of thawing on "double freezing" of cod. Thawing time in relation to quality. Translation No. 317, Torry Research Station, Aberdeen.

MACCALLUM, W A and CHAN, M S 1961 Experiments on the storage of Canadian Atlantic Coast cod in refrigerated sea water. Appendix to *Storage and Transport of Fish in Refrigerated Sea Water*. Bulletin No. 126, Fisheries Research Board of Canada, Ottawa, pp. 41–58.

MACCALLUM, W A and SEPIC, K 1967 Commercial aspects of reprocessing and marketing of sea frozen fish. FAO Technical Conference on the Freezing and Irradiation of Fish, 4th–8th September, Madrid.

MACCALLUM, W A, LAISHLEY, E J, DYER, W J and IDLER, D R 1966 Taste panel assessment of cod fillets after single and double freezing. *J. Fish. Res. Bd Can.*, **23**, 1063–1081.

MACCALLUM, W A, CHALKER, DOROTHY A, DYER, W J and IDLER, D R 1967a Effects of water and dielectric thawing processes on shelf life of double frozen cod and redfish. *Ibid.*, **24**, 127–144.

MACCALLUM, W A, JAFFRAY, JUNE I, CHALKER, DOROTHY A and IDLER, D R 1967b Condition of Newfoundland offshore fish and its influence on quality after single and double freezing. FAO Technical Conference on the Freezing and Irradiation of Fish, 4th–8th September, Madrid.

MACCALLUM, W A, JAFFRAY, JUNE I, CHURCHILL, D N and IDLER D R 1968 Condition of Newfoundland trap-caught cod and its influence on quality after single and double freezing. *J. Fish. Res. Bd Can.*, **25** (4), 733–755.

PETERS, J A, MACCALLUM, W A, DYER, W J, IDLER, D R, SLAVIN, J W, LANE, J P, FRASER, D I and LAISHLEY, E J 1968 Effect of state of *rigor*, and of freezing–thawing processing on storage quality of refrozen cod. *Ibid.*, **25**(2), 299–320.

REAY, G A, CUTTING, C L and SHEWAN, M 1943 Quoted from: Fish proteins with special reference to freezing, by W. J. Dyer and J. R. Dingle. In *Fish as Food*, ed. G. Borgstrøm, Academic Press, New York, **1**, 275–327.

TAPIADOR, D D and CARROZ, J E 1963 Standards and requirements for fish handling, processing, distribution and quality control. *FAO Fisheries Report*, no. 9, 249 pp.

DISCUSSION

Hansen (Denmark): The data given by Merritt show that thawing of fish blocks between heated plates is fairly slow. It should be pointed out that "contact plate" thawing has very interesting possibilities in combination with other thawing techniques, e.g. electric resistance thawing or immersion thawing. The latter combination may give thawing times about two-thirds of those obtained when thawing between dry contact plates, provided that the fish block is not completely compact, but has some voids. The combination gives rapid thawing of shrimp blocks.

Equipment is now being built in Denmark for the combination immersion and contact plate thawing of large blocks. It is intended for batch thawing, the batch being placed in a pallet size container. Manual handling is avoided, all lifting and transport being done by gaff-truck.

Merritt (U.K.): Recently we have carried out experiments in the freezing and thawing of herring for canning. The herring were nobbed (gutted and headed) before freezing in order to

avoid the difficulties of thawing. Partially-thawed fish were canned with good results. It was sufficient to thaw the fish in water at 12°C (54°F) for about 15 min, whereas complete thawing would have required about 60 min. On canning, the fish were sufficiently plastic to permit normal clinching of the lid. In fact, the operations of brining and thawing were combined.

The results of the laboratory tests have been published ("The freezing and cold storage of herrings", *Fishing News International*, Vol. 6, No. 6, June 1967, pp. 44–6). A pilot scale trial carried out in a factory, with 1.5 t of herring has given good results.

MacCallum (Canada): It has been apparent for some time that engineers have assumed that the water used in a water thawer has to be circulated or forced positively across the frozen material. Actually, we do not know how much the velocity can be lowered and still achieve a maximum thawing rate for block-frozen whole fish, using water at a temperature of about 18°C (64°F). From experience, however, we could say that the minimum velocity must be very low. We have thawed fish in a commercial-size water thawer at a maximum thawing rate, using convection transfer of heat from the immersed heating elements and no mechanical circulation. Alternatively, we have used the same arrangements with the addition of conveying the fish at velocities as low as 2½ in/min and noted no difference in the thawing times. The advantages of not using circulators or pumps with attendant piping would seem to be significant, both from the standpoint of cost and the maintenance of hygienic conditions.

Merritt suggests an efficiency of about 70 per cent in the use of purchased energy for thawing blocks in the dielectric thawer. The efficiency, as applied to Newfoundland operations, was calculated to be 57 per cent.

No risk of overheating the fish was apparent from our Newfoundland studies of the conveyorized water thawer.

The cost of partial thawing, using the commercial-type water thawer, was 0.303 c/lb (single shift) and using the dielectric thawer 0.742 c/lb. The costs of complete thawing fish ready for filleting using the water thawer on the one hand and combination dielectric-water thawing on the other, were 0.398 and 0.822 c/lb respectively.

Ranken (Spain): I would like to draw attention to a paper presented at the XIIth International Congress on Refrigeration ("Investigations of some methods of thawing", by A. I. Piskarev, G. I. Krylov and L. G. Lukyanitsa) which reports that the method of thawing has no effect on the quality of the fish. Fundamental and irreversible changes occur during freezing, and the extent of these changes depends on the rate of freezing; no thawing method can return the fish to its condition before freezing.

There was also another interesting paper at the Congress ("The thawing and salting of large fish", by N. A. Golovkin and S. G. Gadziyeva) which discussed brine injection thawing of frozen fish to be used for the production of salted fish.

In thawing methods, we seem to have come full circle since 1958 when Delanie proposed water thawing. Then Torry recommended air thawing followed by the dielectric system. We are now back to water thawing. Apart from the low efficiency of dielectric thawing, which results in operating costs more than twice as high as any other method, not to mention its very much higher capital cost, all the methods of thawing appear equally good from the quality point of view, and the choice must therefore be made on economic and practical grounds in relation to block size, fish variety and processing requirements.

I think Hansen's suggestion on containerization for certain types of operation is a good one. Thawing is only another of the important but short processes in an overall production picture. It's all the handling in between which is so important. Containerization is an excellent idea but it must be an extremely difficult problem in many fisheries, from the logistic point of view. How do you get the containers back to the ships? But the idea is very sound and I think it follows what Slavin has already said concerning tuna.

PART III

ECONOMICS OF PRODUCING AND MARKETING FROZEN FISH PRODUCTS

THE FUTURE OF THE SHORE-BASED FREEZING INDUSTRY

Specific Problems and Techno-economic Considerations in the Shore-based Fish Freezing Industry . . *E. Heen*

Discussion

ECONOMIC FACTORS AFFECTING THE FISH FREEZING INDUSTRY

Economic Considerations in the Production of Frozen Fish and its Marketing and Distribution . *E. S. Holliman*

Economic Appraisal of Different Freezing Methods *C. L. Rasmussen*

Commercial Aspects of Reprocessing and Marketing Sea Frozen Fish . . *W. A. MacCallum and K. Šepić*

Economics of Frozen Fish Marketing *J. A. Crutchfield*

Modern Distribution of Frozen Fish Products *E. Petersen*

Discussion

ECONOMIC CONSIDERATIONS IN THE DEVELOPING FISH FREEZING INDUSTRIES

Primeras Experiencias en la Congelación y Mercadeo de Filetes de Pescado en Perú . . . . *J. Basadre*

Le Développement de la Congélation en Mer et à Terre et de la Consommation du Poisson Congelé dans les pays Tropicaux de l'Ouest africain *R. A. Moal and J. Gousset*

Discussion

PRODUCT DEVELOPMENT

Role of Product Development in the Rational Utilization of Fishery Resources, with Particular Reference to Freezing Fish at Sea . . . . . *R. Kreuzer*

New Product Development—a Conceptual Approach *J. C. O'Sullivan*

New Product Development . . . *P. F. C. Sale*

Product Development and Vacuum Packaging Techniques *J. Aagaard*

Development of Fish Products with Particular Reference to Frozen Minced Fish Muscle (Surimi) *E. Tanikawa, T. Motohiro and M. Akiba*

Effect of Sodium Citrate on the Keeping Quality of Frozen Surimi (Frozen Fish Paste) . . . . *M. Okada*

Discussion

Specific Problems and Techno-economic Considerations in the Shore-based Fish Freezing Industry

by E. Heen

Specific problems and techno-economic considerations in shore-based fish-freezing industry

The development of freezing fish at sea presents a challenge to the land-based fish freezing industry. The volume of fish being frozen has been steadily increasing. Statistics indicate that about 10 per cent of the total world catch is now being frozen at some stage in its distribution and a rough estimate suggests that nearly half of this is frozen at sea.

Vessels with freezing equipment have more freedom in their choice of fishing area and are not faced with the necessity of returning to port with their catch at frequent intervals. Prime fish from every part of the ocean can now be available—nearly in its original state—in any marketing area. As yet, there is no definite trend towards preparation of finished consumer products aboard the vessel, although increased mechanization may ultimately make this possible.

In future, the land-based fish freezing plant will probably become a fish terminal primarily geared to serve the local fishing fleet. Coastal fishing in most parts of the world depends to a great extent on migrating stocks which are subject to great fluctuations. Fish frozen at sea will contribute to the stabilization of the supply of raw material to the land-based industry.

The shore operation has the advantage as far as labour is concerned. Labour costs aboard the vessel may be roughly double those of the shore establishment. Furthermore, fishing vessels are limited to the variety of fish available in their area of operation and cannot usually provide a wide variety of products. The land-based industry will probably have to supplement fresh fish landings from the coastal fleet with semi-finished material frozen at sea and become a distributor and trade in food, with fish being the predominant but not the exclusive produce.

The land-based industry will make every effort to increase the coastal fleet's share in the total fish landings. This will include the development of improved ways of preservation, such as better techniques in chilling, chemical preservatives, irradiation, as well as other methods.

The increasing general demand for more varied prepared consumer products will require great versatility on the part of the land-based industry.

Problèmes particuliers et considérations techno-économiques concernant la congélation à terre des produits de la pêche

La congélation du poisson en mer constitue une sorte de défi lancé à l'industrie de la congélation à terre des produits de la pêche. Le volume des produits marins congelés ne cesse d'augmenter. Selon les statistiques, 10 pour 100 environ des captures mondiales sont actuellement congelés à un stade quelconque de leur distribution, et l'on estime que près de la moitié le sont en mer.

Les navires congélateurs ont davantage de liberté dans leur choix d'une zone de pêche, et ne sont pas tenus de faire fréquemment retour au port avec leur prise. Tous les points de vente peuvent maintenant disposer de poisson de première qualité en provenance de n'importe quel océan—et pratiquement dans l'état où il est sorti de l'eau. Si l'on n'évolue pas encore de façon marquée vers la fabrication à bord de produits finis prêts pour la vente au détail, cette possibilité pourra peut-être se présenter avec le développement de la mécanisation.

A l'avenir, l'usine terrestre de congélation des produits de la mer se transformera probablement en un centre organisé avant tout pour satisfaire des besoins de la flotte de pêche locale. La plupart des pêches côtières sont tributaires dans une large mesure de stocks migrateurs soumis à de grandes fluctuations. La congélation en mer contribuera à stabiliser l'approvisionnement en matière première de l'industrie basée à terre.

L'usine terrestre a l'avantage pour ce qui est de la main-d'oeuvre, qui lui coûte approximativement deux fois moins cher qu'au navire-usine. En outre, celui-ci ne peut traiter que les poissons disponibles dans sa zone d'opérations, et ne saurait généralement fournir une grande variété de produits. Les installations terrestres devront probablement compléter les apports de poissons frais de la flotte côtière par des produits semi-finis congelés en mer, et se faire distributeur et négociant en denrées alimentaires, celles-ci se composant en majorité, mais non exclusivement, de produits de la mer.

L'industrie basée à terre fera tout son possible pour accroître la contribution de la flotte côtière aux apports totaux, ce qui impliquera la mise au point de méthodes perfectionnées de conservation, et notamment l'amélioration des techniques de réfrigération, l'emploi d'agents de conservation chimiques, l'irradiation, etc.

L'industrie basée à terre devra faire preuve d'une grande souplesse pour satisfaire la demande croissante de produits "tout prêts" de plus en plus variés.

Problemas específicos y consideraciones tecnoeconómicas en la industria de congelación del pescado en tierra

El desarrollo de la congelación del pescado en el mar constituye un motivo de rivalidad para la industria que lo congela en tierra. El volumen del pescado congelado aumenta constantemente. Las estadísticas indican que, aproximadamente, el 10 por ciento del total de las capturas mundiales se congela actualmente en alguna fase de su distribución, y una estimación aproximada indica que casi la mitad de esta cantidad se congela en el mar.

Los barcos que poseen equipo de congelación tienen más libertad para elegir su zona de pesca y no se enfrentan con la necesidad de volver al puerto a intervalos frecuentes con sus capturas. Los peces más selectos de cualquier parte del océano pueden comprarse actualmente—casi en su estado original—en cualquier zona de venta. Todavía no existe una tendencia clara hacia la preparación a bordo de productos acabados destinados al consumidor, aunque la mayor mecanización pueda hacerlo finalmente posible.

En el futuro, las fábricas de congelación de pescado situadas en tierra se convertirán probablemente en terminales pesqueras destinadas fundamentalmente a servir a la flota pesquera local. La pesca costera depende en gran medida en casi todas las partes del mundo de las poblaciones migratorias que se hallan sujetas a grandes fluctuaciones. El pescado congelado en el mar contribuirá a la estabilización del suministro de materia prima a la industria situada en tierra.

Las operaciones efectuadas en la costa tienen ventajas por lo que se refiere a la mano de obra. Los costos de mano de obra a bordo de los barcos es posible que sean el doble, aproximadamente, de los costos ocasionados por el trabajo en tierra. Además, las embarcaciones pesqueras se limitan a capturar los peces existentes en su zona de operaciones y por lo general no pueden suministrar una amplia variedad de productos. La industria situada en tierra probablemente tendrá que complementar los desembarques de pescado fresco efectuados por la flota costera con material semiacabado, congelado en el mar, y convertirse en distribuidora y comerciante de alimentos, siendo el pescado el producto predominante pero no el exclusivo.

La industria situada en tierra hará todos los esfuerzos posibles para aumentar la parte aportada por la flota costera en los desembarques totales de pescado. Esto incluirá el desarrollo de mejores métodos de conservación, tales como mejores técnicas de refrigerado, productos preservativos químicos, irradiación, así como otros métodos.

La creciente demanda general de productos más variados preparados para el consumidor, así como en mayor cantidad, exigirá una gran adaptabilidad por parte de la industria situada en tierra.

PROBLEMS relating to the freezing of fish at sea have been matters of concern to national and international organizations for a number of years. With the continuing development of techniques and equipment for the freezing of fish in both processed or unprocessed form aboard the vessel, the question arises as to how these developments will affect the land-based industry. Will they constitute a severe competition or is it possible that freezer ships may assist in stabilizing the activities of the shore plants?

Very early in its development mechanical refrigeration was used to freeze fish aboard the vessel. In 1880, equipment built by German refrigeration pioneers was sent to Russia and installed on freezer barges in the Caspian Sea. The modern freezer ship has come a long way from these early beginnings on an inland sea.

In the late 1920s freezing equipment on motor ships was tried in the halibut fisheries of the North Atlantic and North Pacific. To be economically successful, these ventures required prime fish of the more expensive species. These were soon over-fished and in due course the operations ceased.

The freezing of fish at sea is probably best established in the tuna fishery. It was first developed by the industry of the United States and adopted by other countries with old and new fishing fleets.

In recent years, much attention has been focused on the advances in the freezing and processing of fish aboard deep-sea trawlers. These, to a large extent, have been made possible by the introduction of the stern trawler which offers better possibilities for the processing of fish on board. Britain has been a pioneer in these developments because of her need to find means of exploiting more distant waters to supply her large fresh fish market and processing industry. The merit of freezing fish on board is obvious, for it makes the fish vessel independent of time and place of catch. In principle all fish stocks can be exploited by any nation and brought to any marketing area nearly in its original condition.

It should be remembered though, that freezing is not the only way of attaining such flexibility. The salting of fish at sea, which has been practised for many years on the North Atlantic, to some extent offers similar advantages. However, the market for salt fish is restricted to a few species and usually only good-sized fish are attractive for this kind of processing.

Nevertheless it is interesting to observe that, within limits, the salting of fish at sea had certain impact on the development of the cod fisheries and the marketing of dried salted cod. It encouraged consuming countries to build their own fishing fleet and to provide for the domestic production of the final product. It should be remembered that salting at sea gave rise to the establishment of industrial fish drying plants centralized in a few harbours and making artificial drying necessary to attain a year-round production. In this, there are certain resemblances which may be worthy of note in considering the effect the development of freezing at sea may have on the land-based fish freezing industry of several coasts.

SCOPE OF FREEZING AT SEA

While freezing at sea is certainly not my subject, some reference should be made for comparison's sake and to bring the problems facing the land-based into proper perspective. Table 1 shows the disposition of the world catch for 1965 according to the *FAO Yearbook of Fishery Statistics* (Vol. 21). The volume of fish frozen in that year would be approximately 5 million metric tons. This would include fish that has been frozen at some stage of production between catching and retail sale. In some instances it may have been processed and refrozen or it may have been converted into other products and marketed as canned, cured or fresh fish. It is roughly estimated that nearly half of this volume was frozen at sea. Table 2, also taken from the *FAO Yearbook of Fishery Statistics* (Vol. 21), gives an indication of the trend by comparison of the disposition of the catch in 1965 with that of average for 1957 to 1959. The fact that the volume of fish being frozen has more than doubled, suggests that even the rapid expansion in freezing at sea has not reduced the volume of production of the land-based fish freezing industry.

TABLE 1. DISPOSITION OF THE 1965 WORLD FISH CATCH

	Percentage		*Weight in million tons*
Total world catch	100.0		52.4
Used for reduction and other non-food purposes	31.1		16.3
Used for human consumption:	68.9		36.1
fresh	33.4	17.5	
frozen	10.9	5.7	
cured	15.5	8.1	
canned	9.1	4.8	

TABLE 2. TREND IN DISPOSITION OF WORLD CATCH OF FISH IN 1965 COMPARED WITH THAT OF THE PERIOD 1957–59

	Indices 1957–59 *average* = 100
Total catch	156
Used for human consumption	130
Marketed fresh	120
Frozen	211
Cured	110
Canned	155
Used for reduction and other non-food purposes	278

The freezing of fish at sea is most attractive for such species as tuna, halibut, salmon and some cod species. It has also promoted the exploitation of new stocks such as the South African hake and is gradually being applied in herring, mackerel and shark fisheries.

The greater part of the fish frozen at sea is landed as round or eviscerated fish. The development of the stern trawler in northern Europe was aimed primarily at the freezing of dressed or filleted fish, but in general this has not as yet come about. This reflects the fact that handling and processing aboard the vessel must be done with a minimum of labour. Even if there is a desire to reserve the limited and costly storage space aboard the vessel for the usable parts of the fish, it has been necessary to compromise to the less demanding process of freezing the round or dressed fish. On the other hand, in many fishing fleets, and particularly those of the U.S.S.R., a great variety of vessels with advanced equipment are being introduced and a variety of finished and semi-

finished products are being landed. We may imagine that new tools and equipment for handling the catch and preparing better consumer products will be developed.

However, the costs of labour at sea are roughly double corresponding costs on shore. These costs not only include wages but also the capital costs and running expenses for the increased size of vessel needed to accommodate the larger crew. A deck-hand or machine operator will need a cabin—or at least half a cabin—and will require food, water and the services of a cook. This calls for a larger vessel which needs a bigger engine. The bigger engine will require an additional engineer who in turn will need a cabin, food, water, cooking and so on.

Round, dressed and semi-processed fish landed from freezer trawlers is for the most part marketed as fresh fish during periods when the particular species is in short supply. However, a considerable amount is used as raw material for processing into cured or smoked products or into frozen fillets. This raises the question as to whether frozen fish of different species may be used to advantage for every kind of processing and whether every species is suitable for every processing method. There has been much discussion on the feasibility of refreezing and the conclusions are somewhat confusing.

QUALITY ASPECTS

There are some species that at some stage of their development or in some seasons, have such a tender and delicate texture that, to some palates, an improvement in quality is brought about by freezing and storage. But these are exceptions to the rule. Experience indicates that, in most cases, freezing, thawing and refreezing constitutes a stress on the material and normally involves losses.

It is generally accepted that fat fish lend themselves to freezing and thawing better than lean fish. We have also observed that the water content of fish has some bearing on the effect of these processes. For example, cod and haddock in post-spawning condition suffer greater losses and undergo more fundamental changes than do similar fish in pre-spawning condition. It is very important to understand the peculiarities of the raw material when considering the best way to convert it into useful products. Not every material is suitable for every process.

There are many possibilities of applying new techniques to compensate for the undesirable changes which take place on freezing and refreezing and it is an obligation of the processing industry to study carefully these potentialities. We have several examples that illustrate how the freezing of fish, though once considered as unsatisfactory for a particular purpose, could be turned to a useful process when all the factors involved are carefully analysed.

The sprat, used to produce Norwegian brisling sardines, is one of the most demanding of all raw material used for fish processing. Even minor damage to the skin is considered to be a serious drawback. The fish are extremely susceptible to oxidative changes and the ripening or maturing of the canned product must follow a definite pattern if it is to become a quality product. Nevertheless, the Norwegian canning industry developed to the extent that it was imperative to have a reliable continuous flow of raw material.

Initial studies had indicated that frozen material was not suitable. However, on careful examination of all the factors involved, it was proven that a high quality canned product could be produced from frozen fish if definite requirements were met. The fish had to be frozen in a liquid medium to avoid their sticking together or damaging the skin. The blocks had to be of a suitable size for thawing and had to be protected from damage. It was found that compact blocks well glazed for protection against rancidity could stand the stress during storage provided that the temperature was suitable for the period involved. Thawing procedures had also to be evaluated in the light of the particular requirements of the subsequent brining process. It also became evident that the susceptability of this raw material to damage was so great that the only safe way to handle it was to freeze the fish at sea. In this particular fishery this means that the live fish are brailed from the purse-seine directly into the freezer.

Procedures have been improved over the last decade to the extent that last year 40 per cent of the total production of Norwegian canned brisling sardines was derived from frozen and stored material.

I mention this as an example of what can be achieved when a problem is sufficiently well analysed and attacked by proper means. I do believe that frozen raw material can be used for a great variety of products provided that it is treated in accordance with the particular demands of the subsequent processing procedure.

It is a challenge to the land-based fish processing industry to study and evaluate the potential of sea-frozen fish as raw material. Ways and means of compensating for losses sustained, as for example during thawing, must be studied and the processing method selected accordingly.

INTERNATIONAL ASPECTS OF RECENT DEVELOPMENTS

Exploitation of the freezing of fish at sea to its full potential will certainly have an impact on international trade in fisheries products. The ability to bring ashore a versatile and non-perishable raw material, semi-processed or finished products will permit fishing fleets to operate all over the globe. Fishermen will be able to catch fish in remote waters as well as off inhabited coasts.

As our knowledge of the resources of the sea increases and an international intelligence is developed, we may expect that the mobile freezing fleets will concentrate on the most attractive stocks on the most prolific grounds wherever they may be. We have the tools to take care of the fish resources but we also have the potential to over-exploit them.

The mobility of these new fleets, however, gives them the opportunity to move to new resources from grounds that are over-fished. For example, the greater part of the Soviet fishing fleet was able to move to the more prolific grounds of the Western Atlantic without great difficulty when it became obvious that the Barents Sea was over-exploited, at least for some cod species. Another example of the freezing fleets' versatility is the exploitation of the stock of South African hake which is entering the frozen fish market in increasing quantities.

It appears that the consumer or marketing areas will profit from this development. Generally speaking, the oceans are open to everybody and there is opportunity to harvest the oceans and dispose of the product in protected marketing areas. It is unavoidable that this will lead to some conflict between the local coastal fleets and the ocean-going freezer vessels, and I believe that this will require some kind of international consideration. Also some kind of an advisory body to the freezing industry may be evolved, since this evolution will primarily affect the frozen fish trade.

It is also unavoidable that the well-known conflict between moving gear such as trawls and the stationary gear such as fixed nets and long-lines will be enhanced. In spite of the technical advances in marking fixed gear with lights or radar, collisions by moving gear can never be completely avoided.

It must also be accepted that the ocean-going deep-sea trawler will not be practical in all fisheries. There will also need to be an economic balancing of investment and running expenses against the economic return from the landings and in comparison with other fishing methods.

The purse-seining freezer vessel is well established in the tuna fishery and may soon appear in the herring fisheries as well, but the myriads of small coastal fishing vessels will probably always have a great share of the harvest from the sea. The migrating stocks which inhabit coastal waters for long or short seasons could certainly be exploited by mobile freezer fleets but the question arises as to whether this will be more practical than harvesting by the coastal fleets.

This poses the old question as to why we are fishing and harvesting the ocean. Should this be for the benefit of the fisherman, the processing industry or just that of the consumer? My philosophy is that there is a mutual interest. If a fishing operation does not pay or give the operators a satisfactory reward, it will cease, and no one will benefit. On the other hand, neither the fisherman nor the processor has any prerogative to dictate conditions. The consumer makes the decisions in a competitive market.

THE BASIS FOR A LAND-BASED INDUSTRY

Some fish processing plants may be located in densely-populated marketing areas and utilize frozen raw material of various kinds. Others may be located on the coast in a position where they can be supplied from the coastal or near-water fisheries and where they have satisfactory transportation for the distribution of their products.

In the following, I will restrict my comments to the latter category, the coastal fish terminal with facilities for collecting food fish and primarily using freezing as a means of preservation. Under such circumstances the technical and economic factors will be favourable provided that the activity can be maintained at a reasonable level on a continuous basis and with sufficiently fresh raw material.

To maintain this continuity, land-based industry will probably have to supplement its fresh fish landings with semi-finished material frozen at sea, and may even become a distributor of food with fish being the principal, but not the exclusive, produce.

In most countries today we have to accept the trend that labour will not be available for, or at least will not be satisfied with, a casual or unreliable place of employment. While in former days casual labour could be found to cope with seasonal activities, we now have to use mechanical devices to a much greater extent. But even so, the capital cost of such equipment makes it necessary that it should be used for longer periods during the year.

The main difficulty for the land-based industry today is the perishable nature of the raw material which may spoil in a few hours or, at most, a few days. It is now generally accepted that to obtain good quality frozen products the raw material must be very fresh. Even if *pre-rigor* fish has some undesirable features, the concensus of opinion is that it is better to freeze *pre-rigor* fish than fish that is more than three or four days old. Ice is still the most prevalent cooling medium for fish and it has so many practical advantages that it is hard to find a more suitable method of chilling. The shelf life of the cod species, from northern waters at least, is limited to one week if it is to meet the demands for a good quality frozen product. The fish processing industry is certainly just as interested as the fisherman in finding ways and means of extending this limit.

Chilling in sea-water or even brine may extend the limit considerably. If the temperature can be lowered into the semi-frozen range and if the final product is acceptable even with an uptake of salt, as in the case for a number of products, then the superchilling can double or triple the keeping time. Developments in tank storage and brine chilling are still going on. The advantage, besides retarding deterioration, lies in the possibility of handling catches in bulk and avoiding bruising by immersing the fish in liquid.

Chemical preservation plays little role in handling and caring for fresh fish either for consumption or for processing. Antibiotics have as yet no general application in the fish trade because their merits in controlling spoilage and autolytic changes are so restricted that there is not sufficient reason to take chances on their use.

Sodium nitrite has been used in some countries, but has been more or less abandoned because of its limited effects. It is an excellent preservative in higher concentrations, but the danger is always at hand that such an active reagent may form undesirable compounds. In fact recent studies have proven that highly toxic compounds can be formed with this preservative. Application of active chemicals in food processing is always a hazard if we do not know every detail of their conversion in the biological substrate.

Ionizing radiation has been studied for many years as a possible tool for controlling spoilage and deterioration in fish as well as many other foods. But there is hesitation because even apparently physical treatments can involve the formation of reactive chemicals—in this case, the electron, a chemical agent of the first order. Therefore, considerable advantages will have to be demonstrated before even calculated risks will be accepted.

The formation of free radicals by ionizing irradiation is well known, but the multitude of possible pathways of chemical action makes it difficult to evaluate the effect these may have. Mutations of microbes have been demonstrated, but these may also be induced by many

chemicals and antibiotics. Later during this meeting we will be discussing these problems in more detail.

Even if improved tools do extend the range in which the land-based industry can collect its raw material, there will always be a limit. The industry must face this fact and plan accordingly.

On the other hand, on most coasts there is the possibility of finding use for other species of fish which are more or less unexploited. Species like shark, mackerel and herring, not to speak of octopus, mussels and even the organs of fish are potential sources of useful food products. Product development along the lines of making a broad use of new raw materials is a great challenge to the land-based industry.

A prerequisite for successful development along these lines is a considerable knowledge of the specific properties and peculiarities of the many species of fish. Seasonal variations, the intricate problems related to the food and nutrition of fish and animals of the sea and the microbiology of marine organisms are all important factors.

Even if we are speaking of the fish freezing industry, I would now extend my remarks to include the broader activity of preparing practical and useful products. The industry should not be too narrow in its thinking, but should look for and take advantage of the possibilities of each kind of raw material. If, for example, it proves too expensive to peel small shrimp by hand and there is a machine which will remove the shell efficiently when they are partly dried, then an endeavour should be made to find possible markets for such a product. Where we find fish, which in some seasons at least, does not make a prime frozen product, we should explore the possibilities of preserving it by salting, drying, smoking or canning.

The development of fish sticks, breaded portions and the new line of composite fish products being produced in great variety in Japan and Norway are examples of the possibilities in product diversification which should be studied on a broader scale. Highly adaptable processing and packing machinery may be necessary to attain flexibility, but it is within the realms of possibility for the land-based plant to acquire the necessary tools for a versatile production line.

The supply of raw material may, in general, be more precarious on shore than at sea. Therefore the land-based plant will tend to take better care of what material it has and will avoid waste, while the catching vessel can afford to be more extravagant and select only the most attractive parts of the fish. Some of the more advanced shore establishments are even now endeavouring to make use of the whole fish carcass.

DISCUSSION

Little (U.K.): I think that two interesting points come up here. The first relates to the importance of the time on ice before freezing. Flechtenmacher stated earlier that fish stored 33 h on ice before freezing has not been found organoleptically acceptable immediately after freezing. Heen mentioned a figure of three days as a limit. In view of the industrial use of fish which is stored much longer on ice, should we not reconsider this matter?

The second point concerns the fact that no mention has so far been made concerning the freezing of processed fish products. If the advantage of freezing on land is that we can upgrade fish by reprocessing, then does this present problems or advantages on refreezing methods?

Banks (U.K.): Experiments in the United Kingdom on the effects of holding fish in ice before freezing were designed to answer questions relating to procedures to be adopted at sea in the light of the difficulties of providing freezing equipment on board large enough to freeze at maximum catching rates. It was observed that cod could be kept for three days in ice before freezing before they became unsuitable for filleting and smoking. There was, however, no question of flavour being unacceptable. With haddock, two days was the limit but flat fish, lemon sole and plaice, could be held for five days and still produce a satisfactory fillet when thawed. Again, there was no question of an unacceptable flavour having developed. Herrings require much more careful treatment, but the more modern methods of catching may allow some relaxation of the stringent conditions that have so far been recommended.

Meyer (Federal Republic of Germany): Regarding the length of storage in ice before freezing of fish on land, it can be said that this storage period may last several days.

A content of 10 mg/100 g TMA (trimethylamine) is generally regarded as a correct measure for *good* quality. According to the reports of Torry Research Station as well as our own findings (Meyer, Antonacopoulos and Flechtenmacher, Part I) this value is reached only after 10 to 12 days. It should therefore be possible to obtain a product of good quality after seven to eight or even eight to ten days of iced storage.

It is not possible to control or supervise a prescribed storage time in ice, but it is quite possible to control the limit of TMA content.

Little (U.K.): One of the points that Banks made was that gaping was the quality parameter which was used to define the maximum storage time in ice before freezing. Is this an important point to be considered in this concept of frozen fish? I would have thought that if we are going to freeze fillets into a processed product in retail packs, gaping of the fillet would really not be very important to the housewife. Is gaping a very sensible parameter in this concept?

Banks (U.K.): In reply to Little, on the effect holding cod in ice before freezing has on the amount of gaping when the thawed fish are filleted, the longer the fish are held beyond three days, the more difficult they become to fillet and skin. If the fillets are to be refrozen in consumer packs, good quality cod may be held for a few days more than three days—but poorer qualities would present difficulties.

Slavin (U.S.A.): We have conducted studies that confirm Banks' experience. Peters reported in *Food Technology* that whiting frozen from fish kept more than three days on ice lost quality faster than fish frozen from fish held in ice for shorter periods. Regarding Little's question, I do not think the housewife cares about the product's shelf life. All she cares about is the quality. In fact it almost seems with every new process or increase in shelf life, we increase risk of quality loss due to lack of proper control. One could even speculate that as we develop more processes the quality reaching the consumer does not improve and may in fact decrease. For example, the demand for fresh, unfrozen fish fillets in the United States exceeds that for frozen fillets and natural iced fillets are being sold for about 35 c/lb more than frozen fish fillets.

Fernandez y Fernandez (FAO): Las propuestas sobre la posibilidad de congelar pescado en tierra, incluso después de tres dias de captura, nos parecen desafortunadas. Recordemos que el hombre, el pescador, ha recurrido a través de los

tiempos a varios métodos de conservación. Primero practicó la salazón, mas tarde emprendió la esterilización desarrollando la conservación enlatada. Surge después el empleo del frio llegando a la congelación en base especialmente a que las producciones y capturas se realizan a grandes distancias.

Bajo esta sencilla exposición la congelación debe ser fundamentalmente "insitu". Esta frase debe interpretarse como que no debe haber discriminación, para operar en la mar o en tierra siempre que el producto se encuentre en la fase pre-operatoria, en las debidas y perfectas condiciones.

Hay que distinguir además las diversas clases de peces y crustáceos. El bacalao por ejemplo puede congelarse horas mas tarde después de la captura que la merluza. Esta especie debe ser tratada urgentemente.

Aceptar como un principio la congelación en tierra nos llevaría a una gran confusión y produciría maniobras en los mercados congelando excedentes en detrimento de la calidad. En resumen: Nuestro punto de vista es opuesto a que se acepte sin mas ni mas—es decir sin las debidas aclaraciones—el principio de la congelación en tierra, porque la operación debe practicarse en todo caso immediatemente después de la captura o pocas horas mas tarde.

Danielsen (Switzerland): The Chairman has stated that during our discussions today, we should stick to the privileges of the fishery technologists and not talk about the economic aspects of the different methods for freezing. This is a great privilege but the disadvantage is that our discussions might become rather academic.

Therefore, before it is too late, I will disregard this privilege for the moment and touch upon some economic aspects of freezing raw material at sea for later thawing, processing and then refreezing. I refer especially to Heen's paper on "Specific problems and techno-economic considerations in shore-based fish freezing industry".

The characteristic of the shore-based fish processing industry is the bad utilization of investment. Fishing is very seasonal, resulting in lay-offs of the workers during certain periods and heavy catches during other periods of the year. It is a dream in many countries to freeze the peak and store it until periods with lay-offs and then reprocess it. We have heard that, from a quality point of view, under certain circumstances this might be possible.

It is interesting to have a look at the economics of this procedure. We have to realize that the conditions vary from country to country, so I cannot be exact, but some general comments might be useful.

First, I want to point out that the raw material costs are about 85 per cent of the variable ex-factory costs, which means that the labour costs are relatively unimportant in the cost picture.

In the case of freezing the raw material and reprocessing it later, the extra cost is incurred as follows:

(1) Costs for freezing of the raw material which might easily run up to ½ c/lb.

(2) Storage and handling of raw material. We know that storage costs are high and since round frozen fish and/or skin-on bone-in fillets are rather bulky, costs can easily go to 1 to 1½ c/lb, depending on length of storage.

(3) Extra handling during processing which might run up to ½ c/lb.

(4) The detailed investment costs on shore are difficult to estimate since they will depend upon the method of thawing which is chosen and also upon the degree of utilization of this extra investment. If this investment is only to be used in slack periods, the utilization will be rather low and therefore the costs per unit rather high. In his paper, MacCallum has given costs which might run up to 0.80 Canadian c/lb. This figure seems to me to be rather low and I think that he has assumed a fairly high degree of utilization and a rather low interest rate.

(5) A very important factor is the drip loss which might vary from practically nothing up to 15 per cent. You will realize that this has the biggest impact on costs.

(6) In case of filleting on board and freezing bone-in, skin-on fillets for further processing, we have to consider the extra packing material required. Furthermore, there will be a lower filleting yield because we can never maintain the same standard for the machines on board as we can in a shore-based factory.

(7) In calculating the extra investment costs on board, we have to remember that the degree of utilization of filleting machines will be low and that maintenance and running expenses will be relatively high.

Talking about these extra costs on board, I should like to refer to one of the last sentences in Heen's paper which reads: "The supply of raw material may be, in general, more precarious on shore than at sea. Therefore the land-based plant will tend to take better care of what raw material it has and will avoid waste, whilst the catching vessel can afford to be more extravagant and select only the most attractive parts of the fish."

I strongly disagree! We must remember that, on board, the catching of the fish is the "bottleneck" of the operation. Our experience during the years has told us that the degree of utilization of the factory on board ship is very low and that the catching rate varies greatly from time to time. I would guess that the degree of utilization of the factory on board would be of the order of 50 per cent or even less. Therefore, one way to improve the profitability of the factory trawler is to take better care of the catch.

Perhaps my evaluation of the extra costs in connection with freezing on board and reprocessing has been somewhat superficial. However, I hope that it has given some impressions as to the nature of the problems. You will realize that a real advantage can be obtained by introducing changes aiming at a rationalization of the fishing and the handling of the catch, a better utilization of the catch and, not forgetting a better utilization of the available resources such as investments and manpower. This, combined with freezing on board—be it round freezing, freezing of a semi-finished product or a "ready for the market" product—might be the "golden egg".

Heen (Norway): I would like to reply to Danielsen's remarks. Costs of freezing and storage of sea-frozen fish are high, losses are considerable. For example, in one instance the price to fishermen had to be reduced by 20 per cent when the fish was used for canning. In another case where the fish was used for filleting and refreezing, the costs also required a reduction of 20 per cent of the fish price. Such occurrences are not attractive to vessel owners. Where can the vessel find compensation? It must be in its freedom to select more prolific fishing grounds and hence provide greater catches per unit of effort.

On the other side, the land-based processing industry has a certain advantage in having a continuous operation, but this advantage depends on so many factors that it cannot generally be assessed in dollars or cents. But it can be calculated when these factors can be estimated and this has been done in a few cases. In one case the calculation indicated that the plant would be able to pay approximately half of the additional costs.

In regard to Danielsen's last remark, I think it is justified to say that at sea you may be more extravagant with the raw material because at that stage the considerable transportation costs are not yet incurred.

Economic Considerations in the Production of Frozen Fish and its Marketing and Distribution

by E. S. Holliman

Economic considerations in the production of frozen fish and in its marketing and distribution

The paper sets out the main elements entering into the costs of production and distribution of frozen fish and frozen fish products, discusses briefly the problems of financing new technical developments in this field, and suggests that more extensive studies should be carried out at national and international level to determine costs of production and distribution, and to enable a true economic assessment to be made of the efficiency of new technological developments.

Considérations économiques relatives à la production, à la commercialisation et à la distribution du poisson congelé

La communication fait l'exposé des principaux éléments du coût de production et de distribution du poisson et des produits de poisson congelé; elle examine brièvement les problèmes financiers concernant les nouveautés techniques dans ce domaine et suggère que des études plus approfondies soient effectuées sur le plan national et international en vue de déterminer les coûts de production et de distribution, et de permettre une évaluation économique valable quant à la rentabilité des nouveautés techniques.

Consideraciones económicas acerca de la producción de pescado congelado y su mercadeo y distribución

El autor expone los principales factores que entran en los costos de la producción y distribución de pescado y productos pesqueros congelados; examina brevemente los problemas del financiamiento de los nuevos adelantos técnicos en este sector y propone que se realicen estudios más extensivos, en los planos nacional e internacional, para determinar los costos de producción y distribución y poder hacer una verdadera evaluación económica del rendimiento de los nuevos progresos tecnológicos.

SHORE-BASED PRODUCTION

IN developed countries the traditional development of the freezing process was in shore-based establishments, normally set up at or near the port of landing. It was an unfortunate fact of economic development that in the early years frozen fish was often a poor quality product, produced from raw material of low quality. The conditions of the Second World War further damaged the reputation of the product, particularly in Western Europe, so that after the war the frozen fish industry had to overcome a strong consumer resistance to its product. In order to improve its image, emphasis had to be given to the importance of good quality raw material, in order to produce a product acceptable to an increasingly sophisticated consumer market and one which could safely be marketed under brand names and given wide publicity. This need was often difficult to meet; landings varied widely in quantity, quality and species from day to day even at the largest fish landing points. Prices varied according to the season of the year, the general availability of wet fish within the country which was affected by the level of landings not only at the local port but at the other major fish landing ports, and the general strength or weakness of demand by the wet fish merchants. This meant that freezing plants often found it difficult to obtain regular and adequate supplies of suitable quality fish at steady prices; and this led on occasion to a variation in quality of product which affected adversely not only the particular producer, but the industry generally.

Some processors took steps to overcome this problem by entering into contractual arrangements with vessel operators whereby a part or the whole of their catches was supplied to the plant at fixed prices without going through the normal wholesale market channels. This practice was of considerable benefit to the frozen fish producers but naturally aroused a great deal of opposition from wet fish merchants and distributors who saw substantial quantities of good quality fish being taken off the market. However, the practice now appears to be firmly established and is an integral part of the operations of the vertically integrated catching and processing firms in the fishing industry in many developed countries. The need for steady supplies of raw material at stable prices for processing activities was clearly one of the influences which has encouraged industry integration.

The capital costs of frozen fish production in shore factories are represented by the cost of the factory and the freezing and ancillary equipment such as filleting machines, packing machines, etc. Operating costs include the cost of the fish; labour in filleting, handling, supervizing, etc.; fuel and power; packaging materials, etc. Depending on the method of purchase and handling the raw material there may also be costs of cold storing it before processing and cost of transporting it to the factory from the landing point. Overhead costs consist of administrative overheads, amortization or rental of property and equipment, insurance, etc.

Very little published material has been made available on costs of production of frozen fish in shore-based factories. While this is no doubt largely due to commercial prudence, there are considerable practical difficulties in carrying out comparative cost studies in this field. In the first place, the operation of vertically integrated concerns makes it often difficult to determine the true cost of the raw material; secondly, the varying degree to which the processing concern is involved in the subsequent storage and distribution of the finished product causes difficulty; and thirdly, the product of the factory is often not homogenous over time—it may consist not only of fish but may also seasonally include fruit and vegetables, it may also produce changing proportions of consumer pack and catering pack frozen fish products over two manufacturing periods.

The financing of shore-based freezing plants has normally been carried out by commercial interests, but in some instances loan capital has been made available from Governmental sources under general policies of financial encouragement for fishing industry development.

Production at sea

The pressure to evolve and develop ways of freezing fish at sea arose partly from the considerations set out above, namely the difficulty of securing adequate supplies of high quality fish at the fish landing points. Moreover, the continually declining catch rates on the traditional North Atlantic grounds led producers to study ways of extending the length of voyages and thus improving the ratio of fishing time to steaming time. The major problems were both technical and economic, and early experiments, such as the "Northern Wave" conversion, made substantial contributions towards solving the technical difficulties but very little towards establishing the economic feasibility of freezing fish at sea.

Some development funds were made available in certain countries for experimental work, but by and large in the developed countries the initiative has come from the industry. Again, for obvious reasons, little data has been made generally available on operating performance of freezer vessels, and we have consequently had the spectacle of a considerable number of different techniques being tried out on a commercial scale by owners who have hoped to "back a winner" in their own selected design and technique. Conversion of existing wet fish trawlers, the construction of part-freezers, whole freezers freezing the catch whole, whole freezers filleting the catch before freezing, have all been tried. The first two are now generally agreed to be uneconomic, but there is still no general agreement on the relative efficiency in economic terms of freezing whole or filleted fish nor on the optimum size of such freezer vessels.

There are of course massive difficulties in bringing any cost analysis techniques to bear on this problem, but it may well be necessary to do so if very costly development failures are to be avoided in the future. A major problem is the understandable reluctance of commercial pioneers to make available information which could be to the commercial advantage of their national and international competitors. Differing national policies relating to financing and encouragement of the fishing industry and to pricing and marketing also raise substantial problems. The questions of optimum vessel size and catch rates compared with traditional fishing vessels are also of fundamental importance in making an accurate economic assessment of the advantages of freezing at sea; a great deal of theoretical work has been done in this field, but the inherent variability of the material fed into these calculations, e.g. changing catch rates, changes in density of fish on the grounds, etc., renders the resultant answer of only limited value as a basis for large-scale long-term capital investment.

The costs of production of sea-frozen fish are of course those of a traditional fishing vessel, plus the additional costs of the freezing and storage equipment on board [both direct and indirect (greater vessel size)], the additional labour costs and extra maintenance costs, insurance, etc. These greater aggregate costs may of course be partly or wholly compensated by a substantially greater catch per day at sea and a generally more effective utilization of the high-cost capital equipment represented by the freezer trawler.

It is not intended in this paper to enter into a detailed discussion of costs of sea-frozen fish. It should, however, be mentioned that the costs of shore handling of such fish and its subsequent storage, thawing and distribution are substantial. Moreover it has been a matter for some disappointment in certain quarters that the price realized by sea-frozen fish has often been poor, due partly to avoidable variations in quality which have damaged its market reputation.

It is for consideration whether far more intensive economic studies should be carried out at the national, and subsequently, on the basis of the national studies, at international level, into the costs of operation of freezer vessels and the influence of sea-frozen fish on national markets. While some development finance is available in certain countries for the encouragement of experimental work in freezing at sea, this is of necessity limited and should be channelled into those lines of development which such studies would show to be most promising.

Distribution of frozen fish

For the limited purposes of this paper no distinction will be drawn between sea-frozen and land-frozen fish as such. Inasmuch as the former is typically produced in larger blocks (although some consumer-pack products are being landed in some countries) it generally requires further land-processing before final distribution. The various processes through which such fish can typically pass have been described in another paper (MacCallum and Sepic, 1967); what is surprising is the very variety of such procedures which illustrates the flexibility of utilization of frozen fish which is its main advantage in the modern fish marketing picture. Again, however, the economist must question the cost basis of these procedures and processes, and suggest that the relative cost advantages or disadvantages of the varying practices could well be studied, to indicate more precisely where the balance of advantage may lay, in varying conditions of cost of production, handling and marketing and varying demand functions for the final products presented to the consumer. The growing importance of international trade in fish and fish products emphasizes the need for national producers and distributors to be more clearly aware of their own cost structures, to be able to compete more effectively in such international markets.

Internationally too, those bodies such as FAO whose interest is in the encouragement of fishery development throughout the world, in an orderly and economic manner, are vitally concerned in seeing a more complete and documented picture of operations in this field, which can only be built up from a firm foundation of national studies, perhaps bonded together in an international programme of work to secure comparability of data and harmonization of effort.

Reference

MacCallum, W A and Sepic, K FAO Technical Conference 1967 on the Freezing and Irradiation of Fish, 4th–8th September, Madrid.

Economic Appraisal of Different Freezing Methods

by C. L. Rasmussen

Economic appraisal of different freezing methods

Rationalization of a freezing method depends upon many factors in addition to the costs that are attributable directly to the freezing step. The economic status of a freezing method cannot be accurately determined until all factors are given relative values which are combined in an evaluation involving both objective and subjective ratings. Factors to be considered include requirements of the raw materials, freezing costs, product quality requirements, value of the raw material, what the buyer will pay for a given quality, losses in the process, effects of freezing methods on other steps in the process, where freezing is done, whether the product has been frozen previously, and losses after thawing.

Freezing methods of the future for most products will continue to be the same basic methods now used. For specialized products and uses, however, some of the instant freezing procedures will come into increasing use, particularly as technology expands and the costs of cryogens decrease. Poor handling in distribution and storage can nullify all efforts to improve quality and lower costs. So as we look for freezing methods of the future to give us better foods at reasonable costs, let us be sure that our distribution system is geared to do as well.

Evaluation économique de différentes méthodes de congélation

La rationalisation d'une méthode de congélation dépend de nombreux facteurs extérieurs au coût imputable à la congélation proprement dite. Il est impossible de déterminer avec précision l'aspect économique d'une méthode de congélation avant d'avoir attribué à tous les facteurs une valeur relative et de les avoir combinés en vue d'une évaluation tenant compte à la fois d'éléments objectifs et subjectifs. Les facteurs suivants entre autres doivent être examinés: conditions à remplir par les matières premières, coût de la congélation, exigences en matière de qualité des produits, valeur des matières premières, prix maximum qu'un acheteur acceptera de payer pour une qualité donnée, pertes en cours de traitement, incidences de la méthode de congélation sur les autres phases du traitement, lieu de la congélation, si le produit a été congelé précédemment, pertes par décongélation.

Pour la plupart des produits, les méthodes de congélation de l'avenir resteront sensiblement identiques aux méthodes actuellement employées. Toutefois, certains produits et utilisations spécifiques appelleront une utilisation accrue des méthodes de congélation instantanée notamment du fait du développement des techniques et de la diminution du coût des fluides cryogènes. Tous les efforts entrepris en vue d'améliorer la qualité et de réduire les frais peuvent être annulés par des erreurs de manipulation pendant la distribution et l'entreposage. Certes, nous attendons des méthodes de congélation de l'avenir des aliments meilleurs pour une dépense raisonnable, encore faut-il que le système de distribution atteigne un degré d'efficacité correspondante.

Evaluación económica de diversos métodos para congelar

La racionalización de un método para congelar depende de muchos factores, además de los costos que se atribuyen directamente a la propia congelación. Los aspectos económicos de un método para congelar no pueden determinarse exactamente hasta que se haya dado a todos los factores valores relativos que se combinan en una evaluación en la que participan clarificaciones objetivas y subjetivas. Entre los factores que se tienen que estudiar están: necesidades de materia prima, costos de la congelación requisitos de calidad del producto, valor de la materia, lo que pagará el comprador por una calidad determinada, pérdidas durante la elaboración, efectos de los métodos para congelar y otras fases del proceso, momento de la congelación, si el producto ha estado congelado previamente, y pérdidas después de la congelación.

Los métodos que se empleen en el futuro para congelar casi todos los productos seguirán siendo los mismos que se utilizan actualmente, aunque para productos y empleos especiales se recurrirá cada vez más a los procedimientos de congelación instantánea, particularmente al progresar la tecnología y disminuir los costos de los criógenos. Las malas condiciones de manipulación durante la distribución y el almacenamiento pueden anular todo lo que se haga para majorar la calidad y rebajar los costos. Por esto, al estudiar métodos de congelación que en el futuro produzcan mejores alimentos a costos razonables, hay que asegurarse de que los sistemas de distribución son de la misma calidad.

ANYONE contemplating a new freezing plant has the problem of what type of freezer to install. If he does his homework carefully, he will learn that the most economical system may be, but is not always, the one that freezes water at the lowest cost per pound. His deliberations are akin to the job of making a good stew. Freezing cost is, of course, a main ingredient but not the only one. Other ingredients that must be added to make the stew palatable include the physical requirements of the product (how it is packaged [if it is packaged], its shape and size, and its form); product quality requirements; selling price or what the buyer believes the product and quality are worth to him; losses in processing and post-thaw handling; effects of freezing methods on other steps in the processing; effects of the other steps on freezing methods; and alternate methods for preserving the commodity. Those in the seafood business must add other factors such as where the freezing is to be done and whether or not the fish was previously frozen and by what method. We could go on and make the stew exceedingly complex, but already we have more ingredients than time will allow us to savour and digest adequately.

Anyone who already has a freezing operation and is considering changing or improving the procedures also has a special set of circumstances to evaluate. Many, if not most, are the same as those listed. But a word of caution is directed to those who may want to change the basic method of freezing to achieve a more efficient operation as well as to improve quality. The new method, automated and streamlined as it will be, should not be compared with an antiquated system, with all the benefits being credited to the new freezing method. Suppose the old method involves the use of air-blast in a largely hand-truck-and-tray set-up. One need not abandon the air-blast method to modernize the product handling part of this operation. A comparison of basic freezing methods (such as air-blast, plate, drum, liquid, immersion or spray) must involve only those steps unique in each particular process.

Requirements of the raw material

Materials that are small, uniformly-sized, free-flowing, unpackaged lend themselves to the widest range of freezing conditions. Thus berries, green peas, cut corn, cross-cut green beans, lima beans and meat chunks can be frozen in bulk or in a box by several different methods. Some products can be frozen by only one or two methods because of their shape and size and packaging requirements. Cauliflower, broccoli and asparagus must be packaged first, so freezing is ordinarily limited to plate and air-blast methods. Meat patties and raw shrimp use a method that permits them to remain stationary on a belt or tray or in a package. Packaged items could be frozen with cryogens, but the potential of instant freezing would be minimized because of the insulating properties of the box and wrapper.

In order not to become involved in all of the intricacies of the many methods and procedures that are possible, this comparison is limited to only a few products that best illustrate economic differences among basic freezing methods. Thus, we shall attempt to stress principles, not just differences in application, to freezing products for the retail and institutional markets.

FREEZING METHODS

The making of ice is probably the least costly example of commercial freezing and can thus serve as a reference point or base. Refrigeration is supplied by the least costly method, and heat transfer is liquid-to-liquid through a metal container holding the water. Thermal losses are minor and no cost is involved in moving air. Rapid freezing is not essential, so the least costly combination of coil temperatures, compressor capacities and brine circulation can be employed. Ice may sell at U.S. $6 per s.t. wholesale, or 0.3 c/lb (0.7 c/kg). The actual freezing cost is obviously only a part of this—perhaps half.

Plate freezing has the similar advantage of heat transfer by conduction. However, food products conduct heat more slowly than water, most foods plate-frozen are in containers, and the plate freezer is more costly to build, install and operate. Consequently, plate freezing is considerably more costly than our reference process—water freezing. Labour cost is potentially high but can be reduced by automatic loading and unloading. Plate freezing is more limited in what it can handle than air-blast freezing, but new developments are widening its application.

Air-blast freezing has several advantages. It can be applied to bulk or package freezing, it is adaptable to most products, and it can be operated under a wide range of conditions such as product handling, air temperature and rate of flow and fluidizing techniques. Labour cost can be quite low depending upon the product and its requirements. The main disadvantages of air-blast freezing is the longer time required if the product is packaged first, and evaporation losses if the product is frozen in bulk. The latter can be reduced considerably under proper operating conditions.

A relatively new type of unit is the rotary freezer which is akin to a continuous plate freezer. In one version the cylinder is a double-walled drum with the refrigerant circulating between the walls. The product rides on the outside of the cylinder, so refrigerant-to-metal-to-product contact is maintained. One manufacturer claims a refrigeration requirement of considerably less than air-blast freezing and a floor space area of only one tenth. Evaporation is, of course, virtually eliminated, and maintenance is minimal. Losses from the product sticking to the drum or from breaking when it is removed are claimed to be nil. This unit is not as flexible as air-blast freezing because it is limited to uniform, flat or round materials easily spread on the belt feeder. It does, however, provide a method for essentially plate-freezing unpackaged foods. It is claimed that a 1-in (2.5-cm) thick steak can be frozen in 20 min and small shrimp in 4 min.

Immersion and spray freezing can be done with liquids, including brine or an alcohol such as propylene glycol. The product must be perfectly protected, however. Turkeys, which are usually first wrapped in a plastic film, are quite suitable for such immersion freezing. Immediate contact with the liquid freezing medium gives fairly rapid freezing.

In the cryogenic range, liquid nitrogen, liquid air and liquid or solid carbon dioxide can be the medium. Of these, liquid nitrogen has had the widest commercial development. The extremely rapid or "instant" freezing which is possible by low temperature immersion and spray-freezing probably gives a quality for most products that is nearest to the fresh. Evaporation losses are minimized, but cost of the cryogens is high. Installation cost and maintenance are relatively low.

A new method is now under development which uses dichlorodifluoromethane (Refrigerant 12) as the freezing medium. This relatively costly refrigerant would be recycled in a closed system, so an important item of cost would be the refrigerant that could not be recovered. Rapid freezing and minimum evaporation losses are features of this system. Approval of the use of the freezing medium by appropriate food and drug officials is, however, necessary.

Suppliers of the various freezing systems often claim other advantages, many of which are real, but some are doubtful. We cannot consider them all in this paper. Each potential application must be judged in the light of all facts known to apply. It is quite likely that the deciding factors in some cases may not have been considered herein.

FREEZING COSTS

Cost data were obtained from several commercial sources. I also visited a number of processing plants. To be truly comparative, costs should all be calculated on the basis of equivalent assumptions. This was not possible because of the multiple sources used. I believe, however, that in spite of this reservation, the cost differences are valid. More extensive calculations would not change the basic data but only refine them.

In the brief survey made, I found freezing costs ranging from 0.2 to 10 c/lb (0.4 to 22 c/kg) of product for the common foods now being frozen. This extreme difference represents not only radically different freezing methods and products but also differences in accounting methods. The lowest cost figures are generally for air-blast freezing of unpackaged materials, and for turkeys which are

usually tightly wrapped in plastic film. Typical costs are 0.5 c/lb (1.1 c/kg) or less where volume is large, season is long, and operation is efficient. Plate freezing of packages was found to be around 0.5 c/lb (1.1 c/kg) with the automatic operation less costly than manual. Freezing costs over 1 c/lb (2.2 c/kg) were found only in operations involving low capacity, unusual labour requirements, specialized products, or a high-cost freezing medium.

Fig 1 presents a summary of cost data supplied by one engineering firm. I adjusted the figures to approximately equal annual outputs. Costs are shown for freezing a vegetable such as peas at a rate of 4,000 to 5,000 lb/h (1.8 to 2.3 t/h) in packages in plate freezers and in bulk on belts and trays.

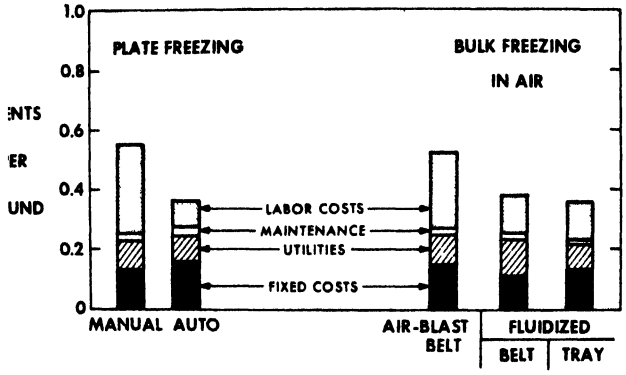


Fig 1. Comparative cost data for various freezing systems

With a product value of about 8 c/lb (18 c/kg), losses would amount to 0.08 c/lb for each 1 per cent loss. If the loss were as high as 5 per cent, the cost per lb would be 0.4 c (0.9 c/kg), about equal to freezing costs. For bulk freezing, the main cause of loss would be evaporation of water from the product. For freezing in the package, product loss would be from broken boxes and product spillage.

Plate freezing or freezing in bulk on belts in an air-blast costs 0.5 c/lb (1 c/kg) or less. The fluidizing technique apparently effects an important reduction in labour costs, and also makes possible a lower evaporation loss. Freezing time is also much shorter in the fluidized systems. The additional investment cost in automatic plate freezing is more than offset by a saving in labour, as compared with the costs of the manual method; the automatic method is nearly 0.2 c/lb (0.4 c/kg) less.

The costs of plate and air-blast freezing as shown are so close that there is little to choose between them on a cost basis only. These costs are doubtlessly lower than will be experienced by most plants because the estimates assume less lost time than might be possible in most installations because of the many labour, raw material and operating problems a plant must experience.

For a general comparison, freezing times for various methods are roughly as shown in table 1 for small fruit and vegetables. Experience at any one plant may be significantly different depending upon the circumstances involved.

Fig 2 shows freezing costs for breaded turkey pieces as supplied by a company that makes both air-blast and

TABLE 1. APPROXIMATE FREEZING TIMES FOR VARIOUS FREEZING METHODS

Package freezing (10-oz [280-g] containers)

Freezing methods	*Time*
Air-blast	3 to 5 h
Plate	½ to 2 h
Bulk freezing—air-blast	
belt	20 to 30 min
fluidized belt or tray	5 to 10 min
Cryogenic freezing	½ to 1 min

TABLE 2. COST COMPARISONS BETWEEN AIR-BLAST AND LIQUID NITROGEN FREEZING

Items	*Air-blast freezing* (*U.S. dollars*)	*Liquid nitrogen freezing* (*U.S. dollars*)
Total cost of equipment installed	131,400	59,000
Annual costs		
Operating, maintenance	8,240	1,200
Liquid nitrogen	—	150,000
Fixed costs—17 per cent of equipment cost	22,300	10,000
Product losses at 46 c/lb (100 c/kg)	46,000	23,000
Total	76,540	184,200
Cost per lb	0.0153	0.0368
(Cost per kg)	0.0330	0.0810

liquid nitrogen (LN) freezers. Pertinent assumptions in the estimate are as follows:

product: cut-up, breaded, 4-oz (110-g) portions;

output: 2,500 lb/h, 5,000,000 lb/year (1,140 kg/h, 2,300 t/year);

losses assumed: 2 per cent in air-blast freezing, 1 per cent in LN freezing;

liquid nitrogen cost: 2.5 c/lb (5.5 c/kg), 1.12 lb required per pound of product.

The difference in cost between these two methods is not minor: it is 2.15 c/lb (4.7 c/kg), 140 per cent more for LN than for air-blast freezing.

To answer the argument that liquid nitrogen freezing permits a much smaller initial outlay of cash (as need for the plant and equipment), let us consider this fact: liquid nitrogen costs for the first year alone, a cost also to be reckoned in the initial capitalization, is more than the difference in plant costs plus difference in evaporation losses, as shown in table 3.

Fig 3 compares the cost of freezing strawberries with LN and with air-blast in a fluidized bed freezer. This

TABLE 3. COMPARISON OF THE FIRST YEAR'S GROSS OUTLAY OF CASH REQUIRED FOR AIR-BLAST AND LIQUID NITROGEN FREEZING SYSTEMS

Items	*Air-blast freezing* (*U.S. dollars*)	*Liquid nitrogen freezing* (*U.S. dollars*)
Plant investment	131,400	59,000
Evaporation losses	46,000	23,000
Total	177,400	82,000
Difference		95,400
Liquid nitrogen cost		150,000

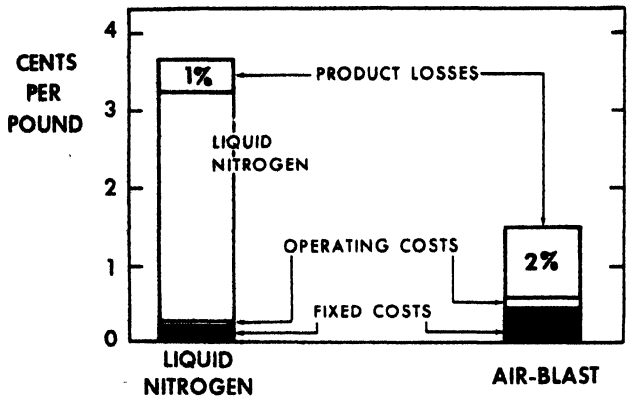


Fig 2. Cost of freezing turkey pieces in liquid nitrogen and air-blast freezers

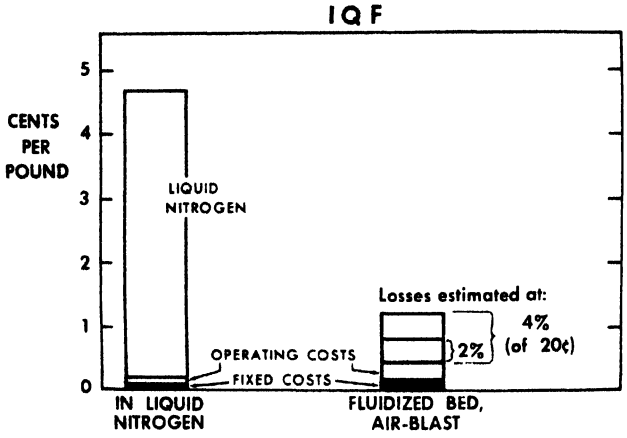


Fig 3. Comparative cost of freezing strawberries with liquid nitrogen and with air-blast in a fluidized bed freezer

comparison assumes LN at 3 c/lb (6.6 c/kg), used at a ratio of 1.5 lb (kg) LN to 1 lb (kg) of strawberries. In spite of the greater cost of operating the air-blast freezer, the only factors of significance in this comparison are the cost of liquid nitrogen and the evaporation losses in the air-blast operation. If freezing costs and evaporation losses were the only two factors considered, the losses would have to be over 20 per cent with strawberries at 20 c/lb (44 c/kg) for the total costs to be equal.

If I can conclude anything at this point about costs, it might be this: the differences in costs among the usual methods of freezing (air-blast, bulk or package, and plate) are likely to be minor. Decision of which method to use will probably be determined by other factors more important in the overall economic picture. If, however, we consider a radically different freezing method, such as using cryogenic materials, cost differences become large and important. Other factors that may overrule freezing cost considerations must indeed be important and/or unavoidable.

PRODUCT QUALITY REQUIREMENTS

The profit motive requires that the least costly method of doing a satisfactory job must be used. But what is satisfactory or best varies by products. Some are extremely easy to freeze. The rate of heat removal is not critical. Other products lose much quality by slow freezing.

An example of the former might be sliced strawberri mixed with sugar. Many in the industry feel that a fa freeze is not even wanted. Apparently the main quali requirement is to avoid microbial growth. An examp of a product suffering from slow freezing is tomatoes. T problem of freezing tomatoes is so great that so far th are not packed commercially. Most other products l between such extremes.

Among the products subject to texture damage l excessively slow freezing are green beans, asparagu melons and whole strawberries. These have high moistu content and lack the physical structure to withstar freezing damage.

Fig 4 shows a photomicrograph of cut sections frozen green beans. The instantly frozen piece close resembles the structure of a fresh bean, having litt cellular damage. At the other extreme is a bean froz slowly. Cell breakdown is extensive, and large caviti develop between the cells. When cooked, beans such this have a poor texture in contrast to the instantly froz beans which are more like the fresh.

Between these extremes is the bean frozen in a matt of minutes, five or six at the most. The physical co dition is greatly improved over the slowly frozen on When cooked, this bean is hardly distinguishable fro the bean frozen instantly.

A similar story for asparagus is shown in fig 5. T small bundles are the vascular tissues, or plumbi system, that carry fluids through the plant. Again, t quickly frozen one has a much better structure than t one frozen slowly, and its appearance is similar to th of the instantly frozen piece.

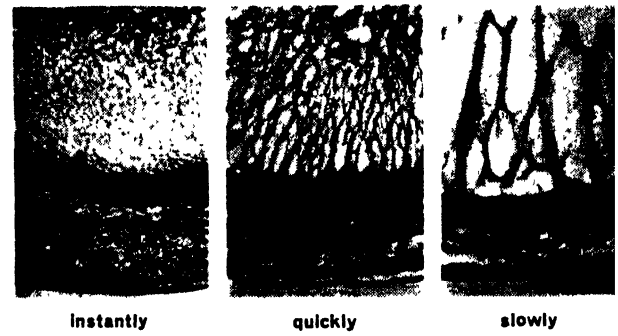


Fig 4. Photomicrographs of cut sections of green beans frozen different freezing rates

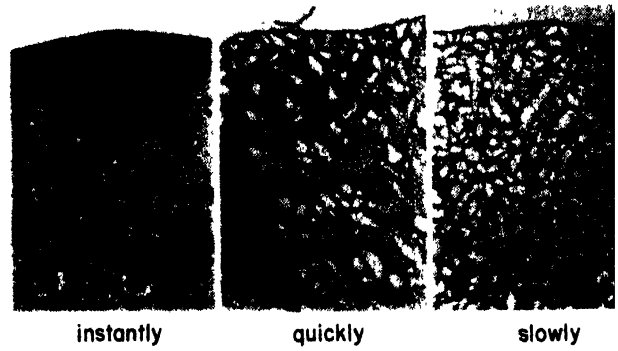


Fig 5. Photomicrographs of cut sections of frozen asparagus at different freezing rates

Freezing of fish and meat effects changes in product quality and the ability of the flesh to hold water. Thus, these products may drip upon thawing. The faster the freeze the less, apparently, is the drip loss. The seriousness of drip depends partially upon how the product is handled during thawing.

We have not made any photomicrographs of fish similar to those I have shown for vegetables, but I should imagine that such photographs would show some differences in cellular structure as a result of various speeds of freezing. Whether or not such differences are important to the ultimate user, however, is the key question.

Freezing with LN or other cryogenic materials produces a quality that is probably closer to fresh quality for most products than any other process now being used commercially so far as physical appearance is concerned. The photomicrographs prove that for vegetables at least, but application of this fact is subject to two qualifications:

(1) For many, and perhaps most products, the physical difference between the instantly and the quickly frozen is not so apparent, and in some cases is virtually non-existent.

(2) One may not need to go to "instant" freezing to obtain all the quality improvement practical in commercial operation. Sensory appraisals at the Western Regional Research Laboratory in Albany, California, have demonstrated that green beans frozen quickly in a very cold air stream have a quality that is hardly distinguishable from LN frozen beans. At the present stage in our research program, it would appear that vegetables such as beans, asparagus and peas frozen in 4 or 5 min may be good enough for even the most exacting demand.

In the rush to extremely rapid freezing, we may have gone from the ridiculous (case freezing) to the sublime in an attempt to achieve our goals when perhaps something in between is all that is needed. Very little is generally known about how fast freezing must really be to obtain a desired quality. We have used cryogens because of their availability and because they do an excellent freezing job, but they may be too costly, especially so if a less costly method can do an equally satisfactory job.

In fast freezing, it is the rate of heat removal that is important, not the temperature of the freezing medium. Extremely rapid freezing takes place in brine or liquid dichlorodifluoromethane at only −35°C (−31°F). The rate approaches that of freezing with LN or solid CO_2. Extremely high air velocities in air-blast freezing coupled with fluidization of the product can also greatly speed the rate of freezing. Coil temperatures below those now accepted as the limit of economical operation might prove feasible. If air at −30° or −40°C (−22° or −40°F) freezes too slowly but air at −60°, −70°, or even −80°C (−76°, −94° or −112°F) would do the job, it might be less costly to provide air at these temperatures than to jump all the way to −196°C (−321°F) at a cost of 3 c/lb (6.6 c/kg). If the bare cost of air-blast freezing is now 0.3 or 0.4 c/lb (0.7 or 0.9 c/kg), we could double or triple that cost and still be way below the more exotic methods.

I note that some of the new freezer developments in both Europe and the United States are using temperatures as low as −60°C (−76°F) in an air-blast system, and −65°C (−85°F) in a drum system.

In this extremely interesting and important matter of applying new freezing techniques, we may well find that the old cliché that coil temperatures below −40°C (−40°F) are uneconomical is no longer true when the alternatives of instant freezing are considered.

SELLING PRICES OF THE FROZEN PRODUCT

This factor has two sides:

(1) The relative value of the product—the higher the value the more that can logically be spent on processing.

(2) The amount of improvement for which the buyer is willing to pay.

Most of the fruit and vegetables frozen are in the 5 to 10 c/lb range (11 to 22 c/kg). High-cost freezing methods may be difficult to justify unless there is no alternative to get the desired quality. On the other hand, an improvement in quality might be easy to justify in fish and meat products, many of which are worth U.S. $1 or more per lb (U.S. $2 per kg), even though the process adds several cents of cost.

The improvements for which a buyer is willing to pay involves both real and imagined benefits. Whether they are real or imaginary hardly matters as long as the buyer will pay. For example, the colour of frozen turkeys within a fairly wide range has no apparent effect on product quality. Yet, because of consumer preference, a bird with a certain colour may be sold at a premium price. A somewhat more costly process to produce this colour can be easily justified.

Someone defined quality as "that for which a customer will pay more because of its presence". The key to that statement in the economic world concerns the customer's willingness to pay. To produce a better quality at a higher cost is futile unless the customer will pay that additional cost. Too often, however, buyers are not willing to pay for as good a quality as processors are able to deliver. This may not even involve instant freezing. It may just be "case-freezing" to save a few cents per case instead of freezing in individual cartons or in bulk. In a market where price is an excessively dominant factor, little encouragement exists to improve the product. About all the processor can reasonably do is to produce the best product the buyer is willing to pay for.

LOSSES IN THE PROCESS

Losses in freezing occur from evaporation and from actual loss of pieces dropping from conveyors and becoming enmeshed in or stuck to belts, conveyors, elevators, etc. Freezing in packages should avoid most of the latter losses. I doubt that these losses, percentagewise, are very large in a well-run operation.

Evaporation losses have loomed large in the battle between cryogenic and air-blast freezing of products in bulk. Just how important these losses are seems to depend, in the propaganda stage, on what one is selling. But let us try to remain objective and see what the facts are.

Evaporation losses, according to one equipment manufacturer, are largely determined by two factors:

(1) Differences in vapour pressure between the product being frozen and the freezing medium.
(2) Length of time the product is subjected to the freezing medium.

After the product is frozen, its vapour pressure drops radically. In fact, this will occur after only the surface is frozen. So the vapour pressure we are concerned with is that prior to freezing. It therefore becomes obvious that the colder the product is before it enters the freezing zone, the lower will be the evaporation losses. Precooling in a moist environment is imperative to minimize evaporation losses.

The vapour pressure of virtually all freezing media is practically zero, so this seems to wipe out any important difference among methods in this respect. What is left, then, is exposure time which must certainly be the most important factor in evaporation losses. This highlights the importance of fluidization in air-blast freezing so that all surfaces are equally exposed to freezing temperatures and quickly surface-frozen. This might make a case for using cryogenics for surface freezing and finishing the job in air-blast.

Whether or not a more costly freezing system should be used to avoid evaporation losses depends on the value of the product and the amount of loss. If a 10 per cent evaporation loss is experienced on a 10 c/lb (22 c/kg) product, up to 1 c/lb (2 c/kg) can be spent on a system to avoid the loss. A similar amount can be spent to avoid only a 1 per cent loss on a U.S. $1/lb (U.S. $2/kg) product. Fig 6 shows the amounts that can be spent to avoid evaporation losses in products of various values. Only extremely low evaporation losses can be tolerated in high-value products. At the other end of the scale, substantial losses can be tolerated on low-value products before a more costly freezing system can be justified, as long as quality is not impaired.

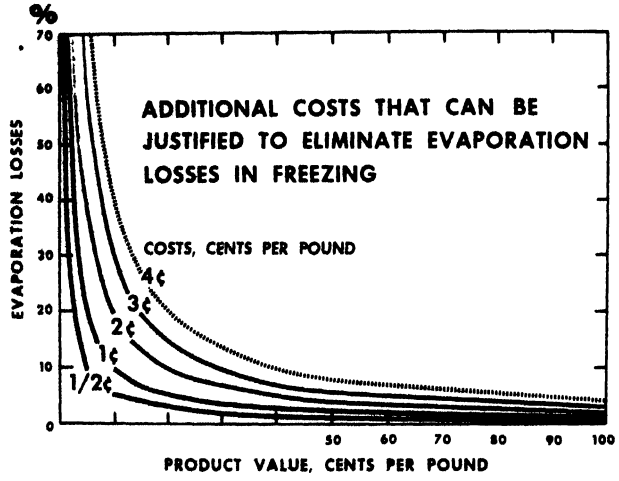


Fig 6. Justified additional costs to eliminate evaporation losses in freezing products of various values

While we might tend to use this chart for judging only cryogenic applications, we must remember that any bulk-freezing system which reduces exposure time will reduce evaporation losses.

Drip losses after thawing are also important in the overall economics. If a freezing system is available that will eliminate or reduce drip losses, it can be evaluated in fig 6 in the same manner as evaporation losses.

The glazing of fish fillets seems to offer one way of minimizing evaporation losses. However, textural and other quality changes caused by a poor freezing method cannot be so modified.

Evaporation losses are important to the processor as they affect the quantity of product he sells. But there is no loss of nutrients. The buyer gets all of them. Drip losses are of no immediate concern to the processor. They are important, however, to the user. Only after the product is thawed do they appear. The method of thawing and cooking may help control drip losses, especially if cooking of a fish or meat product is begun before it thaws. If we look at these problems as a whole, without concern at any particular midpoint, what is important is the amount and quality of food, after preparation by the user, that is actually served.

EFFECT OF FREEZING METHODS ON OTHER STEPS IN THE PROCESS, AND VICE VERSA

Freezing in bulk, in contrast to freezing in packages, permits substantial changes in packaging and warehousing procedures. The essential feature is that packaging and labelling can be put off to the slack season when labour is available, or to a later date when the sales picture for the year becomes better defined.

Frozen peas, cut corn, green and lima beans, berries, cherries, diced fruit and vegetables, and other small uniformly-sized products are stored in large bins with plastic liners. Packaging and labelling are done as needed. Double handling into and out of storage is involved, but the savings in other respects probably more than offset it. Dehydration loss in storage is claimed to be nil.

In recent years, a new storage method has developed. Individually quick-frozen fruits and vegetables are stored bulk in large refrigerated silo-type rooms. Products are moved in and out pneumatically. Claims are made that storage capacity of such rooms is double that of conventional methods and less refrigeration is needed. Dehydration is at a minimum because no air circulates in the rooms. The savings for this type of storage are presumably substantial.

APPLICATIONS UNIQUE TO FREEZING OF FISH

Two factors of unique importance to seafoods are where the freezing is done and whether the product has been previously frozen. Many tons of fish are frozen aboard ships as they are caught. Most are frozen in bulk to be thawed and reprocessed later. It would seem questionable to use a costly instant freezing method in later processing if the fish had previously been frozen by a slower method. The quality differences between the instant and slow methods in the second freezing may well be minor, compared with differences attainable in freezing fresh fish.

If the freezing of fish as fillets and other consumer-type products is done aboard the trawler, the choice of methods

is quite restricted. If cryogens are to be used, the ship must have holding capacity for a weight at least equal to the weight of fish to be frozen while the ship is at sea. An alternative would be to supply the cryogen to the trawler from a supply ship. If the economics of cryogenic freezing is questionable ashore, it becomes even more doubtful at sea. Quality factors would have to be especially compelling.

FREEZING METHODS OF THE FUTURE

Our growing affluence and increasing taste for the better things of life suggest that we might take a "cost be damned" attitude in our desire for top quality. But along with increasing incomes and affluence, industry is experiencing increased pressures from cost squeezes and price strikes by consumers. Cost reduction will continue to be an important if not dominant goal in the food business. I think that conventional freezing methods that can be applied at least cost will continue to produce most of the frozen foods. For specialized products and uses, however, I believe that some of the special freezing practices will find considerable room for growth, particularly as technology expands and the costs of cryogens decrease.

In the matter of reducing the cost of cryogenic materials, I was interested in a recent news item regarding the manufacture of a system for making liquid air, apparently right in the plant where it is used. A cost of 1.25 c/lb (2.75 c/kg) was mentioned for a machine producing 300 lb (136 kg) of liquid air per hour. This is such a logical development that it is difficult to understand why the idea was not suggested years ago. Separation of nitrogen from oxygen and transportation and storage of liquid nitrogen must account for a good part of the 2.5 to 3 c/lb (6 to 7 c/kg) cost of liquid nitrogen. There is danger of oxygen build-up in an immersion-type freezer using liquid air, but in a spray-type unit, the liquid air should present no hazard.

I wonder where the cost curve for producing lower and lower temperatures in a conventional refrigeration system crosses the cost curve for producing liquid air. This relationship, plus the effect of freezing rates on quality should be thoroughly studied to give us a better basis for selecting freezing methods in the future.

A factor that can nullify all efforts to improve quality and lower costs of frozen foods is poor handling in distribution and storage. It matters little how a food is frozen originally if the product is allowed to thaw in an overloaded display case or on a loading platform. Much progress has been made in handling practices in recent years, but there is still room for improvement. So as we look for freezing methods of the future to give us better foods at reasonable costs, let us also be sure that our distribution system is geared to do as well.

Acknowledgments

I appreciate the help of the following who provided cost data and information valuable in my analysis: George L. Andrews, Amerio Contact Plate Freezers, Inc., Cliffside Park, New Jersey; Walter H. Berg, Jr., A. F. Wentworth & Associates, Inc., Tampa, Florida; Howard Cheifetz, Pure Carbonic Company, Berkeley, California; Reese Lamb, Lamb-Weston, Inc., Portland, Oregon; M. R. Overbye, Lewis Refrigeration Co., Woodinville, Washington; Gilbert Powers, Norbest Turkey Growers' Association., South Pasadena, California; A. W. Ruff, St. Onge, Ruff and Associates, Inc., York, Pennsylvania; Thomas Woodson, J. W. Greer Co., Willmington, Massachusetts; Milford S. Brown, Chemist, Western Regional Research Laboratory, USDA, Albany, California (Photomicrographs of frozen vegetables).

Commercial Aspects of Reprocessing and Marketing of Sea Frozen Fish

by W. A. MacCallum and K. Šepić

Commercial aspects of reprocessing and marketing of sea-frozen fish

The authors examine the forces which continue to encourage nations and enterprises to enter the field of freezing at sea. These forces, counterbalanced by local conditions and alternative marketing possibilities, are shown to be insufficient at the present time for still others, particularly in the Americas, to embark upon large-scale freezing-at-sea operations other than in the tuna fishery.

The modes of operation and the uses of equipment aboard and ashore result from decisions based on national or regional needs and on purchasing habits. The review treats with similarities and diversities in procedures and equipment. In some instances European enterprises agree on handling methods and marketing. However, volumewise they still have far to go in this respect. The U.S.S.R. and other countries developing somewhat similar programmes have standardized to a great degree with the serial-building of vessels.

The authors discuss in the context of final quality, trade and profits, the current procedures employed to produce saleable fish in the unfrozen, frozen and canned forms, using fish frozen at sea as raw material. Problems and costs involved in handling, storing, thawing and refreezing or canning are discussed.

Aspects commerciaux de retraitement et de la commercialisation du poisson de mer congelé

L'auteur étudie les forces qui continuent d'encourager les pays et les entreprises à prendre des initiatives dans le domaine de la congélation en mer. Ces forces, qui doivent affronter à la fois les conditions locales et les problèmes posés par le choix des solutions possibles dans le secteur de la commercialisation, apparaîssent actuellement encore trop faibles pour permettre à d'autres pays, notamment dans les Amériques, d'entreprendre des opérations de congélation en mer sur une vaste échelle dans des secteurs autres que celui des pêches thonières.

Les méthodes opérationnelles et l'utilisation de l'équipement à bord et à terre sont le résultat de décisions prises sur la base des besoins nationaux ou régionaux ainsi que des habitudes d'achat. L'article examine les analogies et les différences quant aux méthodes et à l'équipement. Dans quelques cas les entreprises européennes adoptent des critères semblables en ce qui concerne la manipulation et la commercialisation. Cependant, en termes de volume, ces pays ont encore un long chemin à parcourir. L'Union soviétique et d'autres pays ayant établi des programmes plus ou moins analogues ont standardisé dans une large mesure la construction en série de leurs bateaux de pêche.

Les auteurs discutent, sous la perspective de la qualité finale, du commerce et des profits, les méthodes actuellement employées dans la production de poisson destiné aux marchés, non congelé, congelé et conservé en récipients hermétiques, à partir de poisson congelé en mer en tant que matière première. Le document examine et discute les problèmes et les coûts connexes à la manipulation, à l'entreposage, à la décongélation, à la recongélation et à la conservation du produit en récipients hermétiques.

Aspectos comerciales de la reelaboración y comercialización del pescado congelado en el mar

Los autores examinan los factores que siguen estimulando a los países y a las empresas a ocuparse de la congelación en el mar. Estos factores, a los que se contraponen condiciones nacionales y otras posibilidades de venta diferentes, no son suficientes en el momento actual para hacer que otras, especialmente en las Américas, se dediquen a operaciones en gran escala de congelación en el mar, salvo las operaciones efectuadas en las pesquerías atuneras.

La modalidad de las operaciones y la forma de empleo del equipo a bordo y en tierra son consecuencia de decisiones basadas en las necesidades nacionales o regionales y en las características del mercado comprador. El presente análisis se ocupa de las semejanzas y diversidades en los procedimientos y el equipo. En algunos casos, las empresas europeas coinciden en los métodos de manipulación y mercadeo. Sin embargo, en lo que respecta al volumen, todavía tienen que lograr adelantos en este respecto. La Unión Soviética y otros países que desarrollan programas algo parecidos han normalizado estos métodos en gran medida con la construcción en serie de las embarcaciones.

Los autores discuten en su relación con la calidad final, el comercio y los beneficios, los procedimientos que actualmente se emplean para producir pescado vendible en forma no congelada, congelada y en lata, empleando pescado congelado en el mar como materia prima. Se examinan los problemas y los gastos ocasionados por la manipulación, almacenamiento, descongelación y recongelatión o enlatado.

THAT tremendous efforts are being made in many countries to launch fleets of vessels capable of tapping and freezing previously unexploited or poorly exploited resources either close at hand or in far oceans, is apparent from reading almost any current copy of the various trade and technical publications devoted to the fisheries. The various announcements and observations of the foreign vessels arriving at such ports as St. John's or Cape Town, together with reports of large concentrations of vessels on the nearby banks and fishing grounds show clearly that this massive attack on many fishing fronts is still accelerating.

While it is relatively easy to grasp the magnitude of the programmes developed for the construction of freezing vessels, it is difficult to obtain an equally clear picture of the composite shore set-ups, the end uses and the general acceptability of the two million tons of sea-frozen fish being taken each year. Notwithstanding, it is obvious that the drive for frozen, canned and salted fish is based on a need for food at home and for national and foreign earnings. Two principles appear to be involved in the trade in sea-frozen stocks. Firstly, private or state-directed buyers often will want to confine processing at sea to a minimum. However, in the final analysis, competition may force decisions contrary to this principle. Secondly, arrangements for handling, freezing and for all types of processing aboard the vessel will depend to a great extent on the end uses of the catch. In turn, a decision on these arrangements will lead to the selection of the specific type, size and layout of the fishing unit and will greatly influence the cost of construction.

One other feature of this technological revolution in world fish handling is recognition by the important catching nations and particularly by Japan and the U.S.S.R. of the merits of operating fishing vessels from bases close to the distant fishing grounds. Shore bases appear to be the first choice of the Japanese, floating bases that of the Soviets. At the time of his report,

Borgstrøm (1964) noted that approximately 80 per cent of Japan's high-sea catches passed through a global network of bases, the remainder being processed by motherships. According to Brady (1966), about 90 per cent of the Soviet deep-sea fishing is undertaken in areas so distant that huge factory vessels and cargo vessels must work in combination with the fishing units to achieve the transfer of fish from the distant seas to the homeland. Where the oceans can be exploited in either of these ways, many of the fishing vessels need not be equipped elaborately, nor do they need to carry the specialized help required aboard the combination catching and processing vessel and the mothership.

It could be useful for this meeting to examine in broad terms some of the aspects of the composite freezing-at-sea, processing-ashore operations since such examination may engender a useful exchange of technological information and may contribute to a better understanding of the economic possibilities and pitfalls. Among others, the items which we shall air are conditions and requirements for freezing, thawing and storage and the quality before freezing and after thawing where these matters affect trade and profits. Accordingly, this discussion proceeds on the premise that the operations both at sea and ashore are a legitimate charge to the cost of the reprocessed pack. Of necessity this total cost in terms of money and organization must be met if the freezing-at-sea operation is to succeed.

THE PRESSURES FOR FREEZING AT SEA

The most important pressure for freezing and other processing at sea—the need for food and for trade—has been noted already. However, notice should be taken of individual pressures that contribute to the total. Both traditional and new fishing nations need the catches from new grounds. Many of these areas cannot be harvested adequately by vessels that depend upon chilling techniques or have no refrigeration facilities whatsoever. As well, fishing enterprises need a continuous supply of fish for processing and for the marketing organizations, and these supplies must be of acceptable quality. The simplest way to these ends is to control the techniques of preservation, as in freezing. These points are further elaborated in the context of specific operations as the principles involved may have general application.

The shore processor must have an almost continuous supply of material if he is to retain an adequate work force and have sufficient throughput to meet overheads and assure a profit. If chilled landings alone cannot provide this continuity of supply, can frozen landings fill the gap? The answer is "yes" if the frozen fish can be obtained at sufficiently low cost. But the procedures and equipments used to obtain the frozen landings can call for exceedingly complex organization and may be the source of many problems, some of which may be so thorny as to discourage solution. Efforts to obtain continuous supplies of iced or frozen fish must take into account the existing socio-economic facts of life as applied to the fishermen and the fishing community and the particular types of processing feasible for the locality and the times. To illustrate, consider the situation in the Atlantic provinces of Canada where the cost of catching by traditional methods (the trap, the longliner and the short-ranging trawler) has increased faster than has the productivity of the fishing unit. Neither the industry—now predominantly a frozen fish one—nor, with exceptions, the individual fisherman, can thrive on catches available to the trap skiff. Efforts are being made to provide larger seaworthy boats for those who still fish close to shore, and building programmes for iced fish trawlers in Newfoundland and in Nova Scotia particularly have been accelerated greatly. Yet, it is not clearly evident that the offshore trawler, equipped to land only unfrozen fish, will satisfy all future requirements for fish. It is possible that a further change in the socio-economic life of the fisherman might be necessary if, in the long run, production is to show normal growth over and above the goals set for the next few years. An example of such a change—and it might be a minor one—would be the acceptance at a future date of freezing at sea (either "partial" or "full" freezing) as a means of preserving part of the annual catch.

Success in many fisheries that lacked the quantities of good quality chilled fish required for economic operations is now dependent on supplies frozen at sea. Overall satisfactory quality in such table fish as those of the Sparid group, John Dory (*Zeus faber*)(*Zenopsis ocellata*), European hake (*Merluccius merluccius*), squid (*Loligo nidae*), skipjack (*Euthynnus pelamis*), for home use in Japan and in species for canning, e.g. porbeagle (*Lamna nasus*), South-west African pilchards (*Sardinops ocellata*), sprats (*Clupea sprattus*) taken north of Scotland, herring (*Clupea harengus*) from Georges Bank, tuna, king crab (*Paralithodes camchatica*) and salmon (*Oncorhynchus* spp.) depends to a greater or lesser extent on freezing-at-sea practices. A large number of European nations, including the Federal Republic of Germany, Norway, Portugal, Spain and the United Kingdom, embarked on freezing-at-sea programmes for trawled or line-caught fish when it became evident that landed quality in the first-caught iced fish was less than acceptable—and after it was demonstrated with equal emphasis that the vessels could not operate profitably if the iced fishing trips were shortened to ensure acceptable quality at landing.

PRESSURES THAT INFLUENCE THE MODE OF OPERATIONS

Management, having been subjected to the pressures discussed above and possibly moved to positive action in the field of freezing at sea, will establish a mode of operations in response to the interaction of economic, socio-economic, technological and political forces. Let us consider these forces and the actions which may result from them.

Processor's investment

The processor's investment in shore plant and his obligation to provide maximum work in the community will influence decisions on the degree and manner of processing, handling and freezing at sea.

Fish frozen at sea

This product may have to be stored ashore without further processing for many months. While this may stabilize supply, the processor must be prepared to pay

substantial storage costs and avail of raw material having sufficient reserve in quality to offset any effect of storage on the final quality and yield.

Demand, cost and preparation

The demand for a particular species, quality and method of preparation will also affect the mode of operation whether processing is carried out at sea or ashore.

- Some table fish can be partially frozen, stored, thawed and marketed, while others do not respond well to this treatment and require complete freezing at sea, low temperature storage and complete thawing ashore.
- Tuna may be brine- or sharp-frozen at sea using less expensive and less sophisticated equipment than used for cod, flounder and haddock, the latter being currently plate-frozen.
- A market for thawed whole fish prepared from material frozen at sea requires smaller investment in the ship and ship-board equipment than does a market for fillets frozen aboard. Eddie (1964a) outlined some thoughts on this point as seen from the British point of view. However, investment in thawing equipment and in the labour associated with thawing will not be required if the fillets are frozen at sea in a manner (as on some F.R. German vessels) permitting separation without thawing. Moreover, should an appreciably stronger market develop in an area for fillets frozen at sea than for fish frozen whole, the difference in returns for the two products could be applied to reduce any financial deficiency resulting from the greater cost of processing aboard.
- It should be emphasized that typical assessments (as above) are useful only as a general guide. Each type of product and the operations required in its production at sea and ashore require careful study. In the final analysis the difference in the price of the marketed item and the cost of production will be the determining factor. All other factors being equal, the industrialist will select the mode of operations promising greatest profit.

The processor will base decisions on operations at sea on an appraisal of sales possibilities for the various products which might be processed aboard ship. The following are typical of the variety in landings from a single vessel: frozen fillets and salt fish; frozen fillets (alternatively round, beheaded and gutted fish) and frozen animal food; frozen fillets, fish meal, fish oil and canned production.

Often fishing operations are conducted (a) far from the home port or (b) far from the consuming country because the fish are available in quantity only in distant waters. For example (a) Polish catches on Georges Bank may be consumed in the home country or carried there for transhipment to other countries, or (b) shrimp, frozen at sea in the Persian Gulf, may be consumed in the United States or in Canada. Such operations require a supply of fishermen willing and able to spend many weeks at sea, as in example (a), or the employment of fishermen in countries adjacent to the catching area, as in (b). It is important to keep the time that the fisherman is away from home at a minimum. For very long distance fishing the use by the Poles and others of separate vessels for catching improves the possibilities for rotating the crews. The Japanese practice of flying personnel to the home country also recognizes the importance attached to providing adequate leave.

Expenditure of hard currency may be required in exchange for the use of shore freezing or storage facilities located near productive but distant fishing grounds. These expenditures may be avoided if such facilities are provided in the fishing fleet.

In distant fishing areas, shore-based facilities may be non-existent, unsatisfactory, or may not be made available to non-nationals. Certain restrictions or lack of services exist in the North-west Atlantic, the North-east Pacific and to some extent along the West African coast and in other important marine areas and may make it necessary for the fishing vessel or mothership from a distant port to have all facilities aboard.

Dependence on shore facilities for freezing and storing the catch, particularly where these are under the control of other companies or nations, means the loss of valuable control by the catching vessel. It therefore remains for the owner of the catch to assess the importance of control, and if its retention is paramount, to select the mode of processing, freezing and storing suited to the fishery, using the single vessel or combination of vessels that will provide the facilities and efficiency required.

Notwithstanding the above, it may be to the advantage of a fishing nation to operate catching vessels and factory ships from shore bases located near distant fishing grounds. Japan has had arrangements which permit her the use of facilities in Ghana, the Ivory Coast, Liberia, Senegal and other countries (Borgstrøm, 1964). Las Palmas and other ports are used for transhipment. Catching vessels operating under these arrangements need not be equipped elaborately. Specialized help may be concentrated ashore or on motherships rather than spread thinly over a fleet of catching vessels.

Both the mode and the scope of operations for freezing at sea and for processing will be influenced by the availability of credit, organization, manpower and technical knowledge required for a successful venture.

EXAMPLES OF ALTERNATIVE HANDLING OF GROUND FISH

Quality and supply problems

Fig 1 shows by way of example* (1) the current practice in several important fishing areas along the North-east coast of North America and (2), (3) and (4) other practices (not necessarily of equal merit) which might help solve problems of supply and quality in this fishery. It will be noted that (2) describes a procedure which depends on the availability of a number of vessels fitted for freezing at sea and others for handling iced fish or on a number of vessels which can be used on either iced fish or frozen fish trips, (3) a procedure for freezing at sea which corresponds in some degree with that practised

* There are many variations of these operations throughout the world, as well as many distinctly different operations, the numbers of which multiply rapidly if one considers the handling requirements for other species and other end uses.

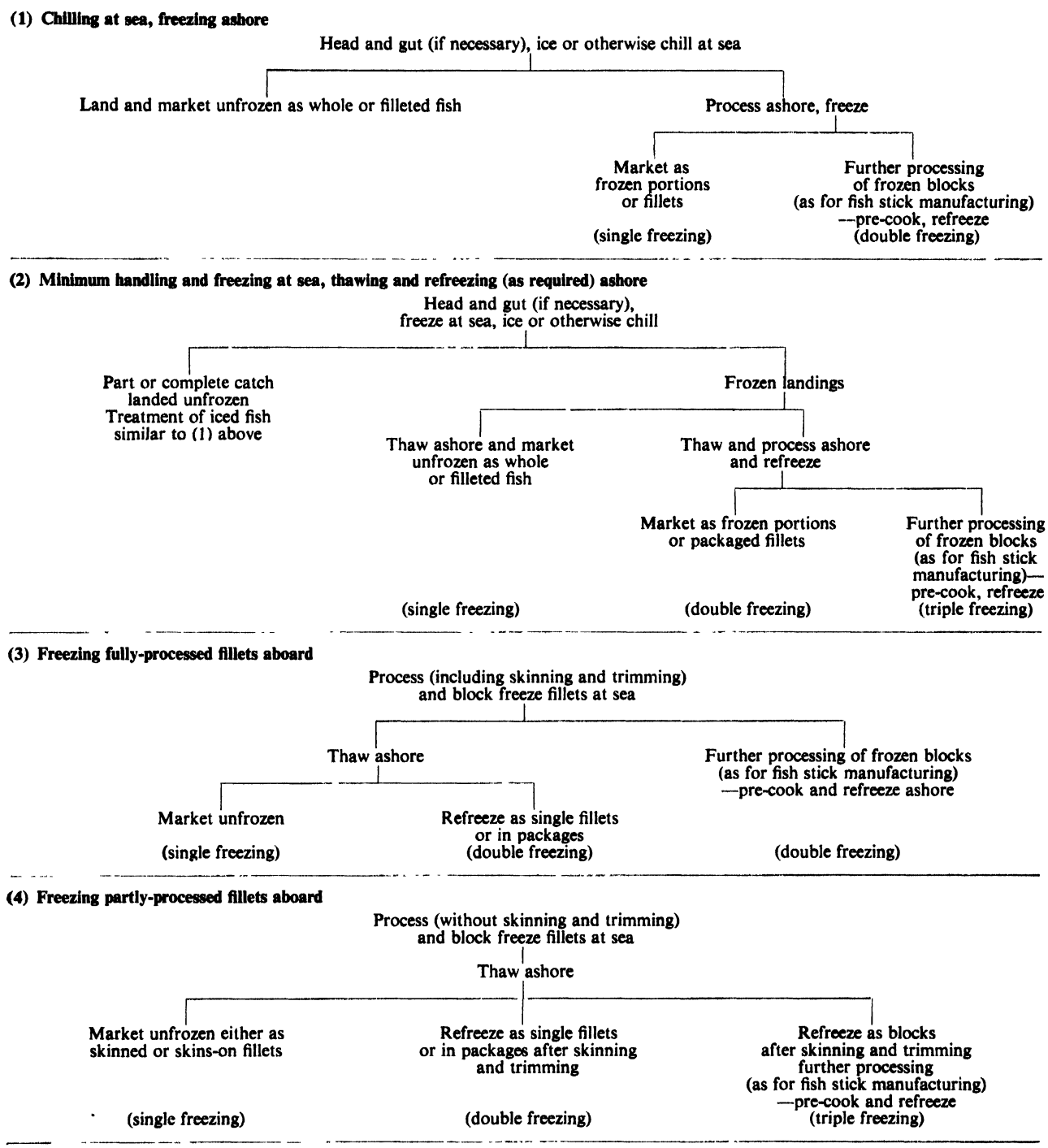


Fig 1. Schematic outline showing alternative methods of handling groundfish to meet the quality and supply problems

in the Federal Republic of Germany, Norway and in other countries, and (4) a procedure tried several years ago in Newfoundland and possibly elsewhere.

A study of the figure impresses one with the fact that double and even triple freezing is commonplace. One realizes, perhaps with a shock, that in scheme (2) responsibility for the organization, the fleet and the plant required for both the first and the second freeze, and for meeting costs of thawing, handling and reprocessing can fall upon the processor. This implies vertical integration which, as explained by Eddie (1964a), may be necessary for the successful handling of the frozen and thawed material according to special methods of production.

European management, taking its catch near the North American coast and processing and freezing at sea for transhipment to the United States via St. Pierre [e.g. fig 1 (3)] can bypass some of the costs and operations associated with example (2). The cost of freezing facilities, combined with the increased costs of catching common to vessels required for operations (2), (3) and (4), demonstrates forcibly the need for vast amounts of capital to finance the private or state-owned fishing enterprises required for operations of these types.

SIZE AND SCOPE OF PRESENT OPERATIONS

The number of vessels and landings given below for freezing-at-sea operations are by way of example only, there being no intention to provide complete data on the world scene.

In 1964, the Federal Republic of Germany had four vessels freezing their entire catches, 31 units equipped with deep-freezing plants, fish meal plants, filleting machinery and oil plants and 13 units provided with deep-freezing and fish meal plants (Meseck, 1965). During 1966, the United Kingdom had over 20 freezer trawlers fishing and many more under construction (Anon., 1966i). Borgstrøm and Heighway (1961) predicted that by 1965 the U.S.S.R would have a freezing-at-sea capacity of 900,000 t. The latest report available (Brady, 1966) shows that as early as 1964 the U.S.S.R. proposed to add 200 freezing-at-sea units varying in size from 3,000 to 40,000 t to the 152 then under construction, all these being additional to the hundreds of catcher-freezer vessels [over 150 in 1961 (Borgstrøm and Heighway, 1961)] and freezers already ranging the oceans. Japanese distant-water tuna ships with freezing facilities numbered 1,301 in 1966 and mothership-type tuna vessels carrying skiffs 181 to 51 motherships and 130 skiffs (Anon., 1966a). In addition, the Japanese employed hundreds of other vessels with freezing facilities including three motherships and 165 catcher boats, 369 salmon longliners, 11 motherships and 369 catcher boats for salmon and six motherships and 26 catcher boats and 59 skiffs for crabs. By 1963 the Japanese operated 110 tuna vessels in the Atlantic (Borgstrøm, 1964). Unofficial reports indicate that this number was increased to about 180 in 1964.

It is suggested by Heen (1967) that a world total of two million tons of fish will be frozen at sea in the current year.

Articles by Tysser in the *Fisheries Year Book and Directory* (1965) are the source of specific data on the efforts being devoted to freezing at sea. Thus, about 10 per cent of the Federal Republic of Germany's total 1964 catch by deep-sea trawlers was frozen at sea. Greek vessels froze about 24 per cent of the nation's catch taken in Atlantic, Mediterranean and middle-water fishing. Israeli vessels froze 16 per cent of the nation's total catch and Spain over 4 per cent. Polish vessels froze 20 per cent of that country's salt-water catch of 244,000 t. Huge tonnages were frozen at sea by the Soviets. It was reported that the output of frozen fish (presumably prepared both ashore and afloat), already constituting more than 57 per cent of all landings, would be increased with fillets to become the chief product. Bulgaria, Yugoslavia and other nations were expected to increase their landings through concentration on freezing at sea, the former 13-fold between the years 1963–83. This would result in annual landings by Bulgarian vessels of over 90,000 t of sea-frozen fish. The Yugoslav plan calls for a sixfold increase in sea-fish catches during the 1964–70 period and annual landings of about 90,000 t by 1970, most of which would be frozen at sea.

The British ports of Grimsby and Hull have shown large increases in landings of frozen fish. In 1966, vessels based at Hull increased their frozen fish supplies by 84 per cent and those at Grimsby by 51 per cent over the 1965 position. In 1966, the ratio of frozen to wet landings at Hull was 1 : 7.5 and at Grimsby 1 : 20. Frozen landings amounting to 25 per cent of the total distant water catch were predicted within a few years (Anon., 1967a).

In general, European vessels freezing at sea land at home ports, but there are many exceptions, e.g. among those of other nations, Polish, Soviet and Spanish vessels freeze fish for sale in Africa, and East German and Polish fish blocks are landed at St. Pierre for transhipment to the United States. The catch of the freezing vessels, if already packed as fillets, may be marketed at home with or without major reprocessing, or may be transhipped to the United Stated or to other European nations. In the main, Europeans make the following use of fish frozen at sea:

> Most frozen fish landed by the Soviets are reprocessed or prepared as food in factories after defrosting; large quantities of these fish are used for the manufacture of ready-made dishes, e.g. fried fish fillets and boiled fish in plastic bags; frozen fish frequently constitutes the basis for continuous manufacturing in the canning plants (Borgstrøm and Heighway, 1961). These editors also report that besides the traditional packs, such as herring, sprats, sardines, salmon, tuna, mackerel, other canned species are encountered—cod, bream (*Sparidae*), grayling (*Thymallus thymallus*), plaice (*Pleuronectes platessa*), sole, pike (*Esox lucius*, *Lucioperca lucioperca*), sturgeon (*Acipenser* spp.) and several whitefish, e.g. *Coregonus clupeaformis*, smoked lamprey (*Lampreta fluviatilis*, *Caspiomyzon wagneri*), etc., together with specific Soviet varieties.

> Hammond (1965) writes that the sale in the United Kingdom of thawed fish, slab-frozen aboard ship, has shown an appreciable rise. He also reports that one proprietary-branded consumer pack of fish, quick-frozen at sea, thawed, processed and refrozen ashore is competitive with proprietary-branded quick-frozen fish prepared from iced landings. The same report asserts that other fish frozen at sea are thawed for processing in the quick-frozen food factories, distributed on the normal principle for sale to caterers or to retail fishmongers for display whole and unwrapped and sold to friers or used for smoking (codlings).

> Blocks of herring, sprats, pilchards and other species frozen at sea in plate freezers are thawed and used for canning as are tuna, porbeagle (*Lamna nasus*) and other fishes frozen loose. Forty per cent of the brisling (*Clupea sprattus*) canned in Norway in the past year was frozen at sea (Heen, 1967). It would appear that the added cost of handling brisling in this manner may be of the order of U.S. $0.03 per kg.

> Other valuable whole fish, e.g. sea breams, John Dory, fishes of the dentex group, etc., are thawed and sold whole or in portions. There are many variations in procedures. For example, Norwegian vessels may land in Hamburg and their catches or porbeagle and other fish may find a market in Italy and elsewhere. Many Norwegian longliners range as far as Newfoundland and the Carolinas for porbeagle and other sharks. The fish are blast-frozen aboard after dressing.

> Norwegian factory ships of the *Longva* type, some of which are noted for their small size, e.g. the *Ronstad*

(Hammond, 1965), block-freeze fillets off West Greenland for export to Great Britain. A few new British factory trawlers (Anon., 1966b), smaller than the *Fairtrys*, have also entered the trade in frozen-at-sea fillets. This may be an indication of a trend towards agreement in principle that sea-frozen fillets have an important future to play in European marketing.

Whole or dressed fish are also block frozen at sea in relatively small Norwegian stern trawlers, e.g. the *Roeggen* (Anon., 1965) and are thawed ashore, processed, refrozen and marketed.

Japanese longliners operating with or without mothership provide both brine and sharp frozen albacore (*Tunnus alalonga*), yellowfin (*Neothunnus macropterus*), big-eyed (*Parathunnus obesus*) and bluefin (*Thunnus thynnus*) tuna for the United States and Caribbean canneries and for canneries in Italy, Yugoslavia and other European nations. Japanese-caught tuna, swordfish (*Xiphias gladius*) and other species are transhipped to Europe via the Canary Islands as are the frozen production of Japanese trawlers which may obtain fishes of the dentex group, John Dory, sea breams and other species. In 1964, the Japanese are reported to have bought salmon from Alaskan fishermen, frozen the fish aboard ship and carried the catch to Japan for further processing (Tysser, 1965). The Japanese carry vast tonnages of frozen fish, e.g. tuna, herring, salmon, marlins (*Makaria* spp.), king crab, etc., to the home country where the fish may be thawed and canned for export and for increasing local use, or the fish may be used in the manufacture of fish sausages, or to meet the needs for low cost, high protein food, skipjack serving the latter purpose to a major degree (Borgstrøm, 1964).

Wide-ranging tuna clippers capable of catching, freezing and carrying a full load of fish play an important part in the success of the U.S. tuna canning industry. U.S. companies also procure king crab frozen at sea near Alaska.

Through the operations of the international division of U.S. and British companies, shrimp, frozen at sea in the Persian Gulf and off the West coast of Australia, is obtained for the home market.

It will be recognized therefore by the student of current trends that many of the productive fishing areas of the world are filled with vessels, many hundreds of which are fitted with freezing and storage facilities and that the frozen catches after minor or major reprocessing ashore are reaching a wide and ever-growing world market.

FACILITIES AND TECHNIQUES AFLOAT AND ASHORE

Vessels

Typical vessels used in freezing-at-sea operations are not described since detailed information is available in the reference material listed, and from many other sources.

(1) Teams of fishing vessels and factory processing and freezing vessels or motherships to handle groundfish, tuna, herring, salmon, king crab, shrimp, etc., and (in the case of motherships) to provide services, supplies and recreation are as follows:

Japanese vessels (Borgstrøm, 1964)
Polish vessels (Anon., 1966e, 1967a)
Soviet vessels (Brady, 1966; Tysser, 1965)
Others: British–Australian operations (Pownall, 1966)
Spanish operations (Tysser, 1965)
The Kuwait National Fishing Company operation (Tysser, 1965).

(2) Soviet non-catching, non-processing carriers or freezer-carriers; the latter usually operating with catchers without freezing operations of their own (Brady, 1966).

(3) Fishing factory ships or super trawlers (capable of operating singly as independent units, catching and processing their catches, or as processing factory ships working with flotillas of smaller catchers). Typical types are:

Soviet vessels (Brady, 1966; Tysser, 1965)
Type ACSA-100 Spanish vessels built for sale abroad (Anon., 1967b).

(4) The freezer trawler—factory type (processing and freezing) or whole fish freezing (Anon., 1967b, 1966f, 1966i; Tysser, 1965).

(5) The part-freezer trawler:

(a) iced and frozen landings (Tysser, 1965; Anon., 1966g);
(b) frozen and salted landings (Anon., 1966h, 1966j).

(6) The tuna clipper and other seiners (Anon., 1964a).
(7) The tuna longliner (Borgstrøm, 1964).

Freezing and storing aboard

Japanese and U.S. companies use both "wet" and "dry" methods for freezing tuna aboard ship. "Dry" methods are used almost exclusively by all nations engaged in catching and in block-freezing fillets and unprocessed groundfish. Great emphasis is placed by Western Europeans on plate-contact methods of freezing. Freon refrigerants are used most commonly in the plate freezers. Ammonia equipment is used extensively for freezing and maintaining the temperature of storages aboard Soviet vessels (Brady, 1966), and freezing is customarily carried out in air-blast freezing tunnels. Commonly quoted storage temperatures for the Soviet fishing and freezing vessels are −25°C (−13°F) and −28°C (−18°F) with −18°C (0°F) for carriers attending the drifters; larger carriers maintain a storage temperature of −30°C (−22°F) (Brady, 1966). The storage temperature most commonly quoted for British freezer vessels is −29°C (−20°F) (Eddie, 1964b; Tysser, 1965; Anon., 1966i).

Tuna may be stored either "wet" or "dry", the latter method being characteristic of operations in the Atlantic. Cartoned fillets and slabs of whole fish are stored dry in rooms refrigerated by pipe coils mounted on the walls and ceiling.

Oxidation during storage and not dehydration is a significant problem in the storage of tuna for canning. Tuna (exception skipjack) for European canneries are stored either gutted, heads-on or gutted and headed while bluefin and big-eyed tuna may be chunked before freezing at sea and stored ashore in the same condition. Thus in

most cases considerable surface is exposed to the air. Sections at the neck and chunk ends may become discoloured and have to be discarded if handling conditions and storage aboard the vessel and ashore are not of the highest standards. Before "dry" freezing on the vessel the chunks are laid on metal trays placed over freezing coils. The fish may drip considerably until freezing stops the action. The use of gauze over the cut surfaces or for wrapping the unfrozen chunks helps to reduce discolouration and waste.

Unloading

Borgstrom and Heighway (1961) report emphasis by the Soviets on the mechanization of discharging, handling and loading equipment. At the time, nine mechanized unloading lines were available at Murmansk alone. Mechanical unloading methods were being tested in Hull early in the present year (Anon., 1967d). A recent article (Anon., 1966c) notes the availability of a system of Norwegian design for automatic transfer of frozen blocks from the freezer to the hold and for unloading and loading factory and freezer trawlers.

Storage ashore

The large cold storages at Murmansk and at other Soviet centres are generally maintained at below −20°C (−4°F), temperatures between −23°C (−10°F) and −29°C (−20°F) being recommended for Baltic herring (Borgstrom and Heighway, 1961). Several new British stores for handling sea-frozen fish are either in operation or will be opened shortly. One such, recently opened in Grimsby (Anon., 1966d), provides about 28,000 m^3 (1 million cu ft) capacity in one room, a clear stacking height of 6 m (20 ft) and brings the combined storage capacity of the owners to 63,720 m^3 (2¼ million cu ft). A temperature of −29°C (−20°F) is maintained in the new storage. In the planning of such new stores, decisions on location, size and arrangements are based on the needs of local processing plants and the need for proximity to quays, which if successfully met, permits direct transfer of fish from the freezer-trawler to storage.

Europeans have found that storages refrigerated with coils on the walls and ceilings contribute less to the oxidation of tuna than do those cooled using forced air. For the most part, the temperature required in the storage depends upon the period of holding prior to canning. It is most desirable to have rooms which can be maintained as required at −20° to −22°C (−4° to −8°F) but such installations are available in only a few locations. The majority of storages at the points of landing and at the canneries maintain a temperature of −18°C (0°F) or higher, and processors must arrange production schedules to match quality resulting from holding at this level. The capacity of cold storages at the canneries is dependent on many factors but in general one equal to the plant production over a 60-day period is considered adequate. The storage should be sufficiently large to handle the complete load of a carrier vessel which can amount to 500–1,500 t. Where canneries collaborate in receipt of frozen fish, storage capacities can be reduced to perhaps one half or one third the capacity of the carrier and can be of the order of 500 to 800 t.

Thawing for canning

Water and air thawing are the most widely used methods known to the authors for thawing sprats, pilchards, herring, tuna, porbeagle and other species used for canning. Frozen whole tuna may be sawed into sections and air thawed or the whole fish may be air or water thawed sufficiently to permit sectioning.

Thawing to permit resale with or without refreezing

Shrimp may be thawed in water, peeled, repacked and frozen or may be breaded or processed in other fashion. Fillets and other fish forms may be thawed in microwaves, e.g. 2,450 Mc/s (Bengtsson, 1964) and in macrowaves, e.g. 38 Mc/s (Jason and Sanders, 1959, 1962a, 1962b) or by electrical conduction methods (Sanders, 1963) and in modified air and water systems. Whole or dressed fish such as sea breams, fish of the dentex family, etc., may be thawed in air or in water for marketing unfrozen. Blocks of other whole or dressed fish (cod, flounder, redfish, haddock, etc.) may be thawed in air (Karsti, 1964; Merritt, 1964), water (MacCallum and Ellis, 1964; Merritt, 1964; Karsti, 1964) or in microwaves or macrowaves for (a) marketing unfrozen as whole dressed or filleted fish or (b) filleting, skinning, packaging (or block-packing) and refreezing.

Fish are subjected to a wide variety of conditions during defrosting. Borgstrøm and Heighway (1961) report that the Soviets defrost in ice over a period of 10 to 100 h, depending on the size of the slabs; defrosting in air is performed at varying temperature levels, either 8°, 15° or 20°C (46°, 59° or 68°F); thawing in liquids gives better results, the times for defrosting varying from 1 to 6 h. These figures are in line with experience in Western Europe, Canada and the United States. According to Karsti (1964) air thawing is preferred to water thawing. However, in conversation with a specialist we have learned that water thawing on a commercial scale is presently being investigated in Norway. It is reported that groundfish, block-frozen at sea by Norwegian vessels, are thawed dielectrically, processed and refrozen (Heen, 1967). Dielectric and humidified air thawers are used by the trade in Great Britain for similar duty. Recently, commercial thawing studies in Canada showed the water method to be well suited for partially or completely thawing block-frozen cod and flounder. Thawing in the former instance is completed in iced storage.

Handling the thawed fish for filleting and refreezing

Thawed fish may be processed immediately or stored in ice or in water at controlled temperatures. Where buffer storages are used the fish do not need to be completely defrosted upon leaving the thawer; however, in general, sufficient heat should be added during the defrosting process to ensure completion of thawing in chill storage.

POTENTIAL FOR SUCCESS OF FREEZING-AT-SEA OPERATIONS

For operations based on the North American seaboard (North-east Atlantic region) the communities in this area may not be ready for a large trade in fish completely processed and frozen at sea for some years to come.

However, it might be feasible to process both iced and frozen groundfish landings. This type of operation is not new. The British have large investments in separate vessels for landing iced and frozen fish. The Dutch (Anon., 1966g) have vessels equipped with both iced and frozen fish holds, and a few Canadian vessels have two holds each, each one being suitable for storing either iced or frozen fish (Walsh, 1965).

The success of large investment in vessels and equipment for freezing after minor processing at sea will depend on (1) availability of crew, (2) a high productivity to cost ratio, and (3) feasibility of the operation from a marketing point of view.

Availability of crew

There will be problems in this area common to many nations and other problems peculiar to particular regions, e.g. the present expansion in Newfoundland and in Nova Scotia of the fleets fitted for landing fish in ice could mitigate against recruiting crews for the part- or full-freezer trawler. Expansion puts a premium on the fishermen's service and removes to some degree the incentive for working under the new conditions that apply to the freezing vessel. On the other hand, Canadians and Americans might well ponder Eddie's (1964a) analysis—applied to the United Kingdom—of the possibilities for increased earnings by the crew for similar days at sea made possible by freezing aboard:

> An important attribute of the British freezer trawlers is that although the landings per ship per annum are some 60 per cent higher than for trawlers preserving the catch in crushed ice, with skippers of equal skill and visiting the same fishing grounds, the crew in a freezer trawler is only 20 or 25 per cent greater in number, while the income of each individual is higher. . . . These factors must tend to offset decreasing recruitment.

The Norwegians too, appear to have no problems in finding crews for their pocket factory ships (see above). However, that nation is in a particularly favourable position for sales, having the privilege of landing sea-frozen fillets in Great Britain.

Productivity to cost ratio

Unpublished studies carried out on behalf of the Fisheries Research Board of Canada show that for a mean catching rate of 16 t (35,000 lb/day), three days total steaming time and two days port time, it may be slightly more profitable to freeze part* of the catch at sea (and to thaw† it ashore) than it is to land all the fish in ice. The preference for freezing part of the yearly catch increases with the value of fish per pound, with lower rates of catching and with an increase in steaming time.

Marketing thawed fish

Quality considerations. Thawed fish have been marketed unfrozen in Europe, Africa and Asia for many years in competition with iced landings (see above). Processed, refrozen shrimp are being marketed successfully in North America in competition with a product originating from chilled landings. Groundfish (e.g. cod, haddock, flounder) are refrozen and marketed successfully in Great Britain and similarly prepared and marketed by the Norwegians. Commercial lots of Newfoundland twice-frozen fish have been marketed also. The particular characteristics of the Newfoundland production are described in another paper prepared for this meeting. Thus, there seems to be little doubt concerning the acceptance of double-frozen fillets if the wholesale buyers are convinced of the suitability of the process. The public will be assured of a good quality, wholesome foodstuff. However, the North American market for thawed fish of some species still has to be investigated.

Price for fish. The market price for fish will undoubtedly affect any decision to proceed with a particular freezing-at-sea operation. In the Fisheries Research Board of Canada cost study referred to earlier, the analysis showing the attraction for freezing part of the yearly catch applied to the conditions outlined above and to the market price of mid-summer 1966.

SOME GENERAL PROBLEMS

The processor will encounter problems and successes in connection with techniques and equipment required in the operation of (1) factory ships, (2) freeze-at-sea, thaw-and-refreeze-ashore operations, and (3) operations similar to (2) having the shore refreezing phase omitted. The degree to which the problems can be met successfully will have bearing on the economic possibilities of the venture.

Quality (actual and imaginary) resulting from freezing-at-sea operations

One unfortunate situation is the association in the minds of some people of thawed or thawed and refrozen groundfish with poor textural characteristics when in fact the texture would be no better were the catch iced for three or four days, then processed and frozen. Textural characteristics in freshly-killed fish of the same species may vary considerably as indicated in another paper prepared for this meeting and in earlier publications (MacCallum *et al.*, 1966, 1967). Such differences often have far more effect on the quality of the product than handling, freezing and storage procedures. Thus, the processor of frozen-at-sea material can be assured that freshly-killed groundfish will for the most part have the same textural characteristics after either single or double freezing and storage. This quality will be very good to acceptable, depending upon the quality of the freshly-killed fish. Any adverse propaganda in this area can be combated by conveying all the facts to those concerned with marketing.

There are, however, real problems to be solved, particularly in the production of sea-frozen fillets (Jones, 1965). It would be helpful to have an opinion from operators on the seriousness of the problem associated with machine filleting *in-rigor* fish aboard ship. If controlled thermal acceleration of the *rigor* processes is of practical help, what will be the cost in terms of extra ship space and equipment and in man hours for manipulating

* The last-caught fish would be landed in ice or depending upon fishing conditions, the whole catch might be (a) frozen, or (b) stowed in ice.

† The study includes, as part of the procurement cost, the added cost of thawing the fish in the shore plant.

the product? There is also the problem of uniformity in the quality (resulting from differences in post-killing treatment) of fillets produced. Jones (1965) discusses this matter thoroughly. We would expect such problems to be accentuated in some catching vessels which operate with motherships or with larger super trawlers, since the catchers carry the fish uniced on deck for many hours or until contact is made with the parent vessel. Again, it would be helpful to have a report on the variation in quality resulting from such handling.

Experienced technologists find major differences in the quality of frozen tuna for canning. The incidence of "green" or honeycombed meat in cooked tuna became a problem in Europe following the purchase of Atlantic-caught species taken in areas which have been fished commercially in recent years only.

Although freezing at sea makes it possible to have the tremendously important tuna canning industry of today, it creates production problems, particularly in countries purchasing foreign-caught tuna for canning. In these circumstances quality cannot be controlled readily, nor can it be assessed until the material is received. The technologist in the factories is faced with the problem of assessing the effect of the quality of the finished product, and the ratio between different finished products of different value. Indeed he must know whether the quality of the frozen material will permit it to be canned profitably. For example, the quality of tuna fish as raw material will greatly influence the percentage of canned fillets, solid packs and flakes obtained and will determine to a great extent the percentage of the catch which will qualify for the various categories of quality of the canned product.

One of the serious problems in the Atlantic tuna trade is the rise in temperature which may occur during transhipment, the latter often having an adverse effect on quality. Closing off the refrigeration system during the period required to transfer the load to shore storage, as required by the labour force, results in partial thawing of the cargo. Refreezing takes place ashore. The same situation can occur during discharge at a European port.

Layouts, equipment and temperature for handling, freezing and storage

Essentially, the need in groundfish vessels fitted for minimum processing at sea is to provide facilities which can be used effectively by the fishermen and are conducive to landing a catch of acceptable quality as judged after processing, packing and storage, transportation and marketing in either the unfrozen or refrozen state. Undoubtedly, the most important aspects of freezer selection are performance and usability. The best engineered unit, refrigerated to capacity, will fail to achieve its purpose unless it can be loaded and unloaded with ease, and unless the layout permits steady, even flow of unfrozen fish for charging and frozen fish to storage.

Simplicity in design is apparent in current installations, e.g. the R12 refrigerated Danish-built horizontal freezers used for freezing fillets on some European vessels and the R22 refrigerated British-built vertical-plate freezers (Anon., 1966f; Eddie, 1964b). In the larger processing and carrier vessels ammonia is the refrigerant in forced air- and plate-freezer installations.

The importance of the rate of freezing should be investigated for each application since rapid rates are obtained at relatively high cost for equipment, refrigerants and maintenance. Quick freezing at rates corresponding to 1 to 2 h in the critical zone of −0.5° to −5.0°C (+31° to +23°F) provides very efficient use of freezer plates and contributes to minimum space requirements for freezers. Some species do not always require such rapid freezing, however. The slow rates of freezing aboard the tuna clipper and the relatively high temperature of storage, −8°C (+18°F), apparently provide adequate handling for material which will be canned in California very soon after landing.

Japanese longliners served as both catching and transportation vessels at the inception of the European frozen tuna trade. Mainly because of economic reasons the present trend is for the catching vessels to stay in the fishing areas of the mid and South Atlantic for as long as possible. The catch is transhipped using harbours close to the fishing grounds, or is transferred from the catching vessel to the refrigerated cargo vessel at sea. To maintain the high quality at freezing, the refrigerated carriers should be outfitted to carry the tuna at fairly constant, low temperature, −20°C (−4°F). Unfortunately, these conditions cannot be met in the first vessels put into service. Where the fish is stored at European ports and transhipped to smaller storages attached to the canneries, the need for constant low temperature, during all but the final days of storing before processing, becomes much more important. Quite large quantities of frozen tuna may have to be cold stored at the canneries several months while fresh material is being processed. While some loss in quality will occur during this time, even at a storage temperature of −20°C (−4°F), such losses are not so serious as to jeopardize economic production if the raw material has had a good history of handling and storage.

Block appearance and dimensions

The standard of quality for fish blocks (fillets) marketed in the United States is high. Major deviations from block sizes and from permissive standards for bones, voids, drip, etc., incur a penalty on price. Traditional fish-exporting nations of Europe and North America have been very successful in meeting and in exceeding these standards by processing and freezing ashore. However, some processors hold the view that it is much more difficult to produce an even-surfaced block of constant dimensions and consistency at sea. If blocks produced at sea cannot meet the standards required in processing plants, these will require sawing. The seller may be paid only for the fish in the sawed block and not for the cuttings although there could be instances when he would be compensated for the latter—at a reduced price—since the cuttings can be used in the production of fish bits, etc.

Thawing procedures and equipment

Thawing tuna prior to pre-cooking has been practised in canneries for many years. In the case of tuna and other species, there are still discussions on such procedures as thawing the whole fish and cutting later or sawing the frozen fish and thawing the sawed portions, on whether

thawing should be completed before pre-cooking and on procedures for pre-cooking frozen-at-sea fish. The procedure adopted should be aimed at the main objective, the economic preparation of tuna with no visible quantities of water in the can. In this context, therefore, the best technological process may not be acceptable if it creates problems in working space and makes too great demands on labour. The best method of thawing from the standpoint of costs is to use free heat while transporting the raw material. This is advisable only if the fish are processed immediately thereafter. This method is practised in California and in Canada in connection with the operation of the catcher-freezer vessels and in many parts of the world where fish are moved from main storages to the canneries.

In selecting thawing equipment, due regard must be taken of the species to be thawed, the degree of processing at sea, the method of freezing employed on the vessel, the characteristics and shape of the frozen block, the form in which the fish is to be reprocessed, marketed and consumed and the cost of thawing. Commercial-scale studies conducted in Newfoundland show the dielectric thawer to be useful for reprocessing blocks of vessel-frozen skins-on untrimmed fillets but not technically and economically best suited* for use in reprocessing blocks of heads-on gutted flounder, whole redfish (*Sebastes* spp.) and heads-off, gutted cod. In the opinion of the Canadian investigators a job of this nature calls for the use of the dielectric thawer in conjunction with (a) an additional thawing device, e.g. a water thawer, or (b) heated storage rooms or water storage in which the temperature is controlled. In the Canadian studies water-immersion thawing (using conveyorized equipment) was shown to be much superior to either the dielectric method or the combination dielectric-water method. In this connection it would be helpful to have more information on the role of dielectric thawing in the Hammerfest operation referred to by Heen (1967). According to reports, other commercial-scale equipment for thawing, e.g. humidified air thawers (Anon., 1964b) and water spray devices (Anon., 1967c), provide the same degree of control against overheating the product as that provided in the conveyorized, water immersion method.

Frozen sprats to be used for canning are thawed in a fine spray of water. This method might also have a future for thawing shrimp to the point where peeling and repacking operations can be performed.

Thawing as affecting yields and processing costs

With the exception of current results on thawing groundfish (to be reported later at this meeting) and some general observations by Karsti (1964), nothing on this subject of particular commercial importance is found in the literature. It would appear that this is an area that could be explored profitably.

Cold storage charges

The cost for cold storage space at the port of landing will vary with the operation and the species handled. Costs at British ports are an extra charge to the purchase price for fish. Some British opinion is that smaller loads of frozen fish, as from the freezer-trawler, are preferred to larger ones from a factory ship, since this reduces shore costs of cold storage. This is particularly important when frozen fish landings are geared to a factory operation, which itself is geared to a regular throughput per day, and when the quality of the end product depends on the time in storage. On the other hand, due to the transportation and marketing situation very large tonnages of Newfoundland frozen fillets, portions or blocks often have to be stored at the point of production while awaiting disposal. The relatively large cold storages now provided could be used for either processed or reprocessed fillets or a portion of each. Thus, there might be little added capital cost for cold storage space for a Newfoundland owner converting from an operation using all iced-fish landings to one using combined iced-fish and frozen-fish landings. For the newcomer to the field, the correct proportion of the capital cost for storage space would be charged to each type of frozen production.

Discharging from the vessel and handling in shore-storages and to the thawer

For minimum costs transfer of the catch from the vessels and into and out of cold storage and to the thawer should involve minimum man-handling; one possibility is palletizing at time of storage ashore, or alternatively at the vessel and retention of the fish on the pallets until their delivery to the thawer is effected. The type, arrangement, number of thawing units and their mode of operation should be considered in any study on handling methods. At least two simple means of transferring blocks to water thawing units can be pictured; one, transfer on pallets using forklift trucks, the other by means of conveyors operating through plug-fitted holes in the wall of the cold storage room. The first arrangement might indicate the desirability of palletizing in the frozen-fish hold or on the dock, the latter a need for a completely different method for handling the frozen blocks.

Washing

In handling relatively large blocks of low-priced unfilleted fish (e.g. flounder) which are not wrapped, there is the chance of contamination with coliforms at one or other stage between removal from the freezer aboard ship and entry to the thawer many weeks and many handlings later. To exercise proper control it might prove that washing the thawed fish prior to entry into iced or refrigerated water storages would be necessary in those instances where the fish do not proceed directly to the filleting or processing line. In any event, all thawed fish should be washed prior to entering the processing line. Such washing, if employing equipment in addition to that used for washing iced landings, will be a charge to reprocessing. Washing might well be effected using water-spray equipment of the type investigated for washing iced fish (MacCallum *et al.*, 1963).

Breakage costs

There will be costs peculiar to reprocessing arising from the breakage of frozen blocks in handling and cold storage. The raw material itself can be recovered from storage and thawed, particularly when water immersion

* The goal in the Newfoundland investigation was the selection of a single thawer or a combination of thawers capable of heating blocks of whole or dressed fish so as to provide various degrees of thawing including complete thawing.

or water-spray methods are used; thus the extra cost arises from the extra man hours in handling, and from the relatively inefficient use of storage space and handling and thawing equipment.

CONCLUSIONS

Freezing-at-sea operations now constitute one of the major links in the processing chain for fish. Two million tons of such material will be handled in the present year.

Among the major producers, Japan depends on these operations for trade and food, the U.S.S.R., Poland and East Germany for food, with recent interest shown in trade. The interest of the United States in freezing at sea stems from its importance in the canning of tuna and in obtaining valuable species, e.g. king crab and shrimp. Nations in Western Europe and those bordering the Mediterranean and others in Africa and in Asia are also making strong efforts to catch and to freeze at sea or in shore plants. The present objective in Great Britain and in Italy is to satisfy home requirements, while the Federal Republic of Germany, Spain and Norway combine this purpose with one of trade.

Exploitation and freezing are conducted on a global scale. Fleets operate in all the known major productive marine areas, the "freezing" nations often fishing close to foreign shores where the local fishery is still geared to a production based on a supply of unfrozen fish.

Modes of operation and handling vary considerably, depending upon national or regional needs and on purchasing habits. Densely populated Europe is showing the way towards uniformity in methods, as in the production of fillets frozen at sea, but still has much to accomplish in this area. The U.S.S.R. and other countries developing somewhat similar programmes have standardized to a great degree with the serial-building of vessels.

The availability of continuous supplies of sea-frozen fish and the assurance of acceptable or better quality are a tremendous boon to the canning and food processing industries. A bright future in operations based on activities both at sea and ashore is assured where other handling, as in chill storage, has proved inadequate, where efforts are backed by strong organization from the catching to the marketing stages, where credit is sound and the enterprise has access to adequate supplies in manpower and technical "know-how". Thus success appears to be dependent to a significant degree on vertical integration.

Notwithstanding, there are technological, engineering and economic problems arising from current procedures. Improvements can be made in procedures at boating and in preparing, freezing and storing tuna for canning. The appearance and presentation of fillet blocks and packages, the design, selection and use of such widely varied items as freezers, refrigerants, cold storages, unloading devices, thawing apparatus and washers represent other areas where improvements of commercial significance are possible.

Acknowledgments

The authors wish to thank Mr. P. M. Jangaard, Scientific Liaison Officer, Halifax Laboratory, Fisheries Research Board of Canada, Halifax, N.S., and Mr. Murray M. Andrews, Packaging Supervisor, Wakefield Seafoods, Inc., Bellingham, Washington, U.S.A., and Dr. G. H. O. Burgess, Officer-in-Charge, Humber Laboratory, Hull, U.K., for help in various researches required in the preparation of this paper.

References

ANON. 1964a Tuna clippers and large seiners. *ASHRAE Guide and Data Book Applications*, New York, pp. 716–718.

ANON. 1964b Ross thawing plant in full operation. *Fish Trades Gaz.*, **4203**, 9–10.

ANON. 1965 Refrigerated stern trawler *Røeggen* from Storvik Mek. Verksted. *Norw. Fishg marit. News*, **12**(2), 29.

ANON. 1966a Fishing round the world. *Wld Fishg*, **15**, 51.

ANON. 1966b The Ranger Ajax project. *Ibid.*, **15**, 32–33.

ANON. 1966c Unloading freezer trawlers. *Ibid.*, **15**, 47.

ANON. 1966d Grimsby's face is changing. *Ibid.*, **15**, 50.

ANON. 1966e Will be a factory for 12 trawlers. *Fishg News int.*, **5**, 15.

ANON. 1966f Octopus freezers built in Spain for Argentina owners. *Ibid.*, **5**, 12, 14.

ANON. 1966g Wet and frozen fish stern trawler. *Ibid.*, **5**, 59–60.

ANON. 1966h Successful debut made by French yard's first stern trawler. *Ibid.*, **5**, 54.

ANON. 1966i New freezer trawler for Grimsby. *Ibid.*, **5**, 46–47.

ANON. 1966j Factory stern trawler *Ole Saetremyr*. *Norw. Fishg marit. News*, **13**(1), 48.

ANON. 1967a *Fishg News*, **2797**, 1, 7, 8.

ANON. 1967b 'Spanish shipyard geared for the series building of fishing craft. *Fishg News int.*, **6**, 30–31.

ANON. 1967c Baader plant for thawing fish frozen at sea. *Ibid.*, **6**, 74, 76.

ANON. 1967d Hull freezer discharge plant still being tested. *Fishg News*, **2796**, 2.

BENGTSSON, N 1964 Electronic defrosting of frozen fish. In *Fish Handling and Preservation*, OECD, Paris, pp. 159–171.

BORGSTRØM, G and HEIGHWAY, A J 1961 *Atlantic Ocean Fisheries*, Fishing News (Books) Ltd., London, pp. 55–63, 283–315.

BORGSTRØM, G 1964 *Japan's World Success in Fishing*, Fishing News (Books) Ltd., London, 312 pp.

BRADY, P Focus on the Soviet fleet, Part 2—Transport, 1966 processing and factory ships. *Fishg News int.*, **5**, 26–28, 30, 32, 33.

EDDIE, G C Freezing at sea: technical and economic aspects. 1964a In *Fish Handling and Preservation*, OECD, Paris, pp. 13–29.

EDDIE, G C Some recent developments in mechanical 1964b engineering in the deep sea fishing industry. *Proceedings of the Institution of Mechanical Engineers* (Process Engineering Group), London, pp. 3–23.

HAMMOND, A E Fish freezing, storage, transport and mer- 1965 chandising. *Fisheries Year Book and Directory*, 1965–66, ed. H. F. Tysser, British–Continental Trade Press Ltd., London, pp. 69–76.

HEEN, E Freezing at sea—freezing ashore. *Fiskaren.* 1967

JASON, A C and SANDERS, H R Dielectric thawing of fish. 1959 *Proc. Xth Int. Congr. Refrig.*, Copenhagen, 3, paper 4–53, 19–24.

JASON, A C and SANDERS, H R Dielectric thawing of fish. I. 1962a Experiments with frozen herrings. *Fd Technol., Champaign*, **16**(6), 101–106.

JASON, A C and SANDERS, H R Dielectric thawing of fish. II. 1962b Experiments with frozen white fish. *Ibid.*, **16**(6), 107–112.

JONES, N R Freezing fillets at sea. In *Fish Quality at Sea*, ed. 1965 World Fishing and The White Fish Authority, London, pp. 81–88.

KARSTI, O Thawing frozen fish in moist air. In *Fish Handling* 1964 *and Preservation*, OECD, Paris, pp. 173–179.

MACCALLUM, W A and ELLIS, D G Water thawing of frozen 1964 cod blocks. *J. Fish. Res. Bd Can.*, **21**, 115–131.

MACCALLUM, W A, MULLAN, M W and PLAUNT, ISABEL N 1963 Factors influencing the effectiveness of fresh fish washing operations. *Ibid.*, **20**, 1231–1244.

MACCALLUM, W A, LAISHLEY, E J, DYER, W J and IDLER, D R 1966 Taste panel assessment of cod fillets after single and double freezing. *Ibid.*, **23**, 1063–1081.

MACCALLUM, W A, CHALKER, DOROTHY A, DYER, W J and 1967 IDLER, D R Effects of water and dielectric thawing processes on shelf life of double frozen cod and redfish. *Ibid.* (In press.)

MERRITT, J H Thawing blocks of frozen cod in air and in 1964 water. In *Fish Handling and Preservation*, OECD, Paris, pp. 181–189.

MESECK, G *Fisheries Year Book and Directory*, 1965–66, ed. 1965 H. F. Tysser, British–Continental Trade Press Ltd., London, pp. 25–29.

POWNALL, P C Shell fishing in Western Australia. *Fishg News* 1966 *int.*, **5**, 19, 21–22.

SANDERS, H R Electrical resistance thawing of fish. *Proceed-* 1963 *ings 5th International Congress of Electro-Heat*, Wiesbaden, No. 403, 5 pp.

TYSSER, H F *Fisheries Year Book and Directory*, 1965–66, 1965 ed. H. F. Tysser, British–Continental Trade Press Ltd., London, pp. 13–76, 80–83, 85–89, 91–93, 95–101, 102, 103, 107, 111.

WALSH, B Canada's first freezer stern trawlers. *Can. Fisherm.*, 1965 **52**(3), 27.

Economics of Frozen Fish Marketing

by J. A. Crutchfield

Economics of frozen fish marketing

This paper presents an analysis of the reasons for and future implications of important developments in marketing frozen fish.

In the developed countries, consumer response to frozen packaged fillets, sticks and portions has been excellent. This has led to greatly increased emphasis on brand identification and therefore on need for high and uniform quality. The insistence on better quality control at all stages has been a major factor in the strong tendency toward vertical integration of fishing, processing and marketing functions. The result has been a faster, more flexible and lower cost flow of fish to the consumer.

Horizontal combination has also been increasing, partly to share the cost of storage, transportation and display facilities with other frozen foods, and partly to realize the benefits of mass promotion of "families" of branded food products.

The division of processing functions between shore-based and floating facilities is a cost problem, for which there is no single general answer. In high wage nations there is a tendency to move as many functions ashore as possible, with new emphasis on freezing whole fish at sea for later processing.

The function of the freezer is entirely different in underdeveloped areas, where most fish is sold whole in open markets. New techniques are developing that permit mass handling and transport of whole frozen fish over surprisingly long distances and at very low cost. It is important, however, to prevent this desirable development from stifling the slower process of modernizing and expanding the indigenous inshore fisheries.

Aspects économiques de la commercialisation du poisson congelé

La présente communication analyse les motifs et les incidences futures des développements importants dans le domaine de la commercialisation du poisson congelé.

Dans les pays développés, l'accueil des consommateurs aux paquets de filets, de bâtonnets et de portions de poisson congelé a été excellent. En conséquence, l'accent a porté de plus en plus sur l'identification des marques de fabrique et il est devenu nécessaire d'assurer une qualité élevée et constante. L'exigence d'un contrôle de qualité amélioré à tous les stades constitue un facteur essentiel de la forte tendance à la concentration verticale des fonctions relatives aux opérations de pêche, au traitement du poisson et à sa commercialisation. Le circuit, du lieu de pêche au consommateur, s'en est trouvé accéléré et assoupli, avec une réduction du coût.

Les combinaisons horizontales ont également augmenté, d'une part en vue de partager le coût de l'entreposage, du transport et des étalages avec d'autres aliments congelés, d'autre part afin de tirer parti de la promotion de vente massive des "familles" de produits de marque.

La répartition des opérations de traitement du poisson entre installations de bord et à terre pose un problème de coût, qui n'a pas de réponse générale unique. Dans les pays à salaires élevés, on a tendance à effectuer le maximum d'opérations possibles à terre et, depuis peu, à congeler en mer le poisson entier, en vue de son traitement ultérieur.

La congélation a une fonction totalement différente dans les régions en voie de développement, où la plupart des poissons sont vendus entiers au marché. De nouvelles techniques sont en cours d'élaboration pour permettre la manipulation en masse et le transport du poisson sur des distances étonnamment longues, pour un coût très minime. Il importe toutefois d'éviter que ce développement, pour souhaitable qu'il soit, n'entrave le processus plus lent de la modernisation et de l'expansion de la pêche côtière locale.

Economía de la comercialización del pescado congelado

En este documento se estudian las razones de hechos importantes en cuanto a la comercialización del pescado congelado y sus futuras repercusiones.

En los países desarrollados, la respuesta del consumidor a los filetes, barras y trozos congelados y empaquetados ha sido excelente, y con este motivo se concede mucha mayor atención a la identificación de la marca y, por consiguiente, a la necesidad de una calidad buena y uniforme. La insistencia en un mejor control de la calidad en todas las fases ha sido uno de los principales factores de la fuerte tendencia hacia la integración vertical de las funciones pesquera, de elaboración y de comercialización: el resultado ha sido que el pescado llega al consumidor con mayor rapidez y flexibilidad, y menor coste.

La combinación horizontal también está aumentando, en parte para compartir los gastos de almacenamiento, transporte e instalaciones de exposición con otros alimentos congelados, y en parte para obtener los beneficios de la promoción masiva de "familias" de alimentos registrados comercialmente.

La división de las funciones de elaboración entre las instalaciones a bordo o costeras es un problema de coste, al cual no puede darse una respuesta única. En las naciones con salarios altos existe una tendencia a que se realicen en tierra el mayor número posible de operaciones, y un renovado interés por la congelación a bordo del pescado entero para su elaboración posterior.

La función del congelador es completamente diferente en las regiones subdesarrolladas, en donde casi todo el pescado se vende entero en el mercado libre. Se están estudiando nuevas técnicas que permitan la manipulación y el transporte a distancias sorprendentemente largas y a precios verdaderamente bajos del pescado entero congelado. Es importante, no obstante, evitar que esta deseable mejora perturbe el proceso, más lento, de modernización y expansión de las pesquerías costeras indígenas.

WHEN the new technology of freezing and cold storage was introduced to the ancient industry of fishing, a whole chain reaction of advances —and problems—began. While the shift to the freezer is now an indisputable fact, the attendant alterations and vexations continue to this day to affect such varied considerations as the methods and places of marketing the seafood, the form in which it is to be presented, the needed transportation and, perhaps above all, the customs and attitudes of consumers in both the developed and the developing countries.

THE DEVELOPED COUNTRIES

On balance, it is self-evident that the freezing techniques more than justify their use. Properly frozen fish (given the *appropriate terminal and transportation facilities) can* bring the equivalent of really fresh seafood to areas otherwise technically out of reach of any seaport. Moreover, they take the question mark out of fish buying in areas where freshness has formerly been, at best, dubious at some times of the year.

Basic marketing advantages of frozen fish

Equally important, the freezer provides a partial offset to the abiding problem of most fisheries—the stubborn refusal of supply and demand to coincide on a seasonal basis. Modern freezer techniques permit, at a cost, much better adjustment of peak to average capacity for the whole processing marketing sequence. As a highly desirable corollary, it probably increases the annual demand for fish, since total consumption at a given average price is likely to be greater if a uniformly good product is *available throughout the year.*

Less obvious effects of the rapid growth in frozen fish technology are related to the processing marketing sector of the industry. In the more developed nations of Europe and North America, growing public acceptance of frozen fish has been accompanied by growing appreciation of its convenience, and a consequent growth in demand that is highly responsive to rising incomes. Packaging leads inevitably to the opportunity for (and virtual necessity of) brand identification, and the forging of a continuing link between the consumer and the individual processor. The matter of quality then becomes a matter of direct and paramount concern to the individual firm, where it mattered little in the more conventional types of fish marketing.

Packaged frozen fish and quality control

It is not surprising, then, that growth in the frozen fish industry has been marked by sudden new interest in quality control and in uniformity of branded products. The ripples from this development have continued to spread. The increased public demand for more uniform quality, coupled with brand identification, focused the attention of processors on weaknesses in marketing and handling facilities for those groundfish destined for frozen packaging. In some cases this was simply a matter of inadequate physical arrangements. In many established fishing ports dockside markets had been set up for an entirely different type of operation and were quite incapable of adjusting to the needs of the frozen fish processors for fast handling and processing of high-quality fish for frozen packages. In addition, the central wholesale markets in most older areas—for fish and for most other perishable products as well—are badly located with respect to modern transportation facilities and frequently are seriously congested as a by-product of generally unplanned urban growth. As one might expect, there has been a strong tendency for frozen fish processors to locate in new areas, where access to the desired transportation services is more satisfactory and where the overall speed of the operation can be increased.

Pressure toward integration

These requirements of frozen fish marketers have been an important factor, though not the only one, pushing the fishing industries of Europe and North America toward vertical integration. To some extent, integration simply has come about as the ultimate way to ensure the quality of packaged fish by exerting direct control at every stage from vessel to retail display case. In another sense, it stems from cost advantages accruing to any large-scale marketers of food products—that is, the ability to rationalize physical functions in the assembly and distribution of a variety of related food items and to make much more effective use of large-scale management techniques.

The matter goes still deeper than this, however. Until the late 1940s the crude pricing mechanisms developed in waterfront markets and in subsequent wholesaling sufficed to indicate, at least in a general way, where and when fish should be marketed. Modern food industries, however, require more precise demand analysis resulting in more accurate adjustment of varieties, quantity and quality to the demands of diverse groups of consumers. The old pricing mechanism simply is not sensitive enough to provide producer and processor with the proper signals. The tendency toward integration of marketing, processing and fishing activities thus reflects competitive pressure to achieve a finer adjustment to consumer demand as well as ensuring more adequate quality control on a continuing basis. In effect, integration permits the shortening of lines of communication and more direct control over the timing, scale and composition of fish landings, together with more effective adaptation of product mix to changes in consumer preferences. Modern freezing technology permits these adjustments to be made far more effectively than was possible when marketing was limited to fresh fish alone.

Horizontal combination in food marketing

The growth of packaged frozen fish has also introduced a new element in the horizontal organization of fish marketing. It is no secret that the high cost of marketing fresh fish is due largely to the necessity of providing entirely separate storage, transportation and handling facilities. On the other hand, frozen fish is a reasonably good neighbour to all sorts of other products (including other frozen foods) which can be merchandised, advertised and transported jointly at very considerable savings in unit costs. So it is quite natural to find in the developed countries a strong tendency for horizontal combination of firms producing complementary kinds of frozen foods and other processed food products. In addition to economies of scale associated with physical handling and management, there are obvious advantages in creating a "family" of brand names that can be jointly advertised with mutually reinforcing effect.

It should be pointed out that integration is a relative term. It is not necessary that the marketing firm have full control over all fishing activities or over all processing activities of related firms. Frequently the same result can be achieved through loose contractual arrangements that involve only partial combination of functions.

Whichever technique is adopted, the ability of the large, integrated firm to "internalize" its demand analysis, physical flow decisions, and procedures designed to protect the quality of frozen fish give it a very real advantage over the decentralized specialist.

It is significant that the meat and poultry industries have led the way in quality control and technological improvement through integration. Both are direct and effective competitors of the fishing industry, not only in terms of price, but for favoured space in the display facilities of retail stores.

Processing afloat or ashore

From the standpoint of the economics of fish freezing *per se*, the most intriguing questions involve the proper assignment of functions between vessels and shore-based facilities. One is always tempted to generalize from the experience of his own country, and it seems clear that in the United States wage rates, union policies and relative costs of maintaining equipment afloat and ashore militate against any important future for ship-based operations in filleting, freezing and packaging. But not all decisions are

that clear cut. It may well be possible to "split the difference" by developing further techniques for freezing whole fish—an operation that requires relatively little in the way of additional labour inputs aboard a modern fishing vessel while still permitting significant improvement in the ratio of fishing days to total trip time. Processing can then be handled ashore, where labour and technical requirements are much less severe. As a different alternative, the tuna industry has had outstanding success in preserving the whole fish in chilled brine, thus permitting the vessel to fill its holds before returning to port with no necessity for elaborate and expensive equipment aboard the vessel.

On balance, however, recent experience in the private enterprise economies suggests that rising real incomes and the necessary increase in wages and salaries required to attract men to sea-going occupations will shift more and more of the processing toward shore rather than toward the sea. Though mechanization of larger vessels is the order of the day, it is likely to be directed primarily toward further advances in the freezing of whole fish and the processing of fish meal only.

Like all generalizations, this is obviously subject to qualifications, depending on consumer preferences in the individual nations and relative costs of labour and capital. There can be no doubt that the long run market position of frozen fish products in the developed countries will strengthen, relative to that of fresh fish and of most other types of processed fish. Many open questions remain, however, as to the proper scale, location and degree of automation of the physical processes involved in putting the right products in the right place at the right time.

THE DEVELOPING COUNTRIES

Basic fish marketing structures

At risk of belabouring the obvious, it should be pointed out that the physical environment in which fish are marketed in most developing countries is vastly different from that in the high income areas of Europe and North America. At present and for the foreseeable future, most shoppers in Africa and Asia prefer to buy fish (and virtually all other food products) in open markets rather than in stores. The reasons are found partly in low income levels in these areas and partly in customs that make the market a centre for the social life of the community.

As a result, the whole pattern of frozen-fish marketing in developing countries must be geared to the limited number of nodal centres served by good roads and where frozen storage is available. From these centres fish can then be fanned out by a network of simple retail peddlers to provide surprisingly good range. At best, however, a distribution system of this type is severely limited in realizing the potential advantage of freezing techniques. The outlying cold stores, for any volume of operation, must be close enough to production or import points so that insulated trucks can be used. Mechanical refrigeration on vehicles is a persistent headache in developing countries, not only because of the extreme difficulty and cost of maintenance but also because of the difficulty of developing backhauls that will use the equipment fully.

Consumer preference

In addition, the marketing of fish in most developing areas of the world is complicated by a centuries-old prejudice against buying anything but whole fish (except, of course, in dried or cured form). The antipathy—undoubtedly based on sad experience—indicates a perfectly rational desire of the buyer to judge the freshness of his purchase. Moreover, dietary habits in many parts of the world reflect a distinct preference for whole fish, usually boiled and used as a sauce or condiment with starchy foods.

It can hardly be expected, therefore, that development of frozen fish marketing methods parallel to those of the more sophisticated economies will be seen in these nations for some time to come. Elements of the practice may show up in the larger cities, but even there, they will be restricted in scope by the difficulty of linking frozen fish to a larger group of frozen products, and will primarily serve a small high-income class.

Role of the frozen chain in developing areas

On the other hand, a series of developments in West Africa (and possibly elsewhere) illustrates a promising role for frozen fish marketing in developing countries. The essence of the operation is the ability to freeze cheap trawl-caught fish rapidly and effectively aboard the vessel and then to feed the frozen product into a marketing chain designed to deliver a product indistinguishable from fresh whole fish at the lowest possible cost. In the West African countries—Ghana and Nigeria, for example—the technique has been picked up by private European and African operators and by some of the state-operated enterprises as well, and developed to a surprisingly high degree. In Nigeria, upward of 35,000 t of whole frozen fish per year is now pouring into the country from Russian, Japanese and Polish distant-water trawlers, and plans are afoot to equip Nigerian vessels to provide fish on the same basis. The same kind of activity is found in Ghana and other West African countries.

The key to the operation lies in the speed and economy inherent in handling bulk frozen fish. The essential ingredients are: (1) fairly large holding capacity at the principal ports of entry; and (2) small upcountry cold stores, within one day range by insulated vehicles and of sufficient size to accept full truck lot deliveries and to service small lot retailers who will peddle the fish in open markets throughout the adjacent hinterland. Properly handled, the upcountry cold stores can be kept to very small size and capital cost in relation to the flow of fish through them. The ability to deliver a good quality product without the use of complicated mobile refrigeration equipment frees the operation from most of the technical difficulties that have beset frozen food operations in tropical areas in the past. It should also be pointed out that marketing operations of this type permit the use of trawl catches of mixed sizes—the typical tropical output—without the complications of filleting or other processing of a wide variety of fish taken in the same gear.

Obviously, certain requirements must be met before a system of this type can work. In particular, a reasonably good road system and telephone communications are essential if rational short run allocation of supplies is to

be achieved. In addition, it is absolutely imperative that a regular supply of frozen fish of the proper uniform quality be available. In this respect, it seems likely that the most rapid and efficient development of the marketing system can be achieved through the use of supplies from the wide ranging deep-sea trawl fleets of the international fishing countries. This suggests the desirability of separating the problem of developing a cheap large-scale source of high protein food from the related but different problem of developing a local fishing industry.

Consumer acceptance of frozen whole fish

In view of ancient custom and prejudice, will it be difficult to develop a market for this new product? Perhaps; but the obstacles do not appear overwhelming. In the West African countries, it proved relatively easy to overcome the suspicions of the "fish mammies" by offering to buy back any unsold fish. There may well be a general tendency to underrate the adaptability of consumer demand to new products when the need for protein food is really great. In four or five countries in the Gulf of Guinea area, consumer acceptance has been surprisingly good, even in areas where fresh fish from the sea were virtually unknown.

Impact of local fisheries

The effect of the additional supplies of fish generated under a programme of this sort is likely to assume political importance far beyond its economic significance, because of its impact on prices of local inshore catches. In virtually all developing countries, those engaged in the inshore (and inland) fisheries are culturally, economically and perhaps physically isolated from the rest of the community. Development of these scattered fisheries is as much a social and political problem as an economic one. Any programme to expand the quantity and geographic outreach of fishery products in areas where protein needs are great should include plans to minimize depressive effects on the local fisheries.

This is not an insurmountable task. The experience of several of the African and Asian nations indicates that the impact of bulk-frozen fish can be centred on areas and groups of potential consumers for whom fresh fish—the logical alternative—are rarely if ever available. Nigeria is a case in point. It is clear that the tremendous increase in the import of frozen whole fish has dealt a much harder blow to the import of dried fish from Europe than to the market for local fresh fish. Similarly, the development of a frozen-fish chain in Ghana has been designed specifically to supplement protein food supplies, with little or no impact on the modern small boat fisheries which are emerging as the logical outgrowth of the Government's programme to assist the indigenous fisherman and the isolated fishing village.

SUMMARY AND CONCLUSIONS

There can be no doubt that frozen fish products have established themselves as a major product group in the developed countries of the world; and their position should strengthen over time. The flavour and texture, closely resembling fresh fish, combine with durability, convenience and variety to make the end product highly desirable in an urbanized and relatively high-income community. If developments in North America and Europe are any indication, it would appear that the greatest contribution of the freezer is not to expand the low-income market for fish in general, but rather to increase the competitiveness of fish products *vis-à-vis* meat, poultry and other processed protein foods for middle- and upper-income families.

From the standpoint of the developing economies, frozen fish products as such are likely to remain a luxury beyond the reach of the great bulk of the population. In these areas the principal use of modern freezing techniques is simply to extend the outreach and reduce the distribution costs of what are still, from the standpoint of the final consumer, "fresh" fish.

Since the poor seem destined, unfortunately, to remain with us for a long time, it behoves us to find other processing techniques that are less demanding in terms of quality control, capital equipment and skilled maintenance. Irradiation, as indicated in other papers in this Conference, offers some real prospects along these lines. Highly encouraging developments in the field of fish protein concentrate also promise to extend the coverage of protein-from-the-sea in a new dimension, though marketing problems arise from its basic characteristic as a medicine rather than an appetizing food product.

In many other areas, however, and in the production of a whole spectrum of seafood products, cold-technology has made and will continue to make a notable contribution to the growth and economic health of the fishing industry.

Modern Distribution of Frozen Fish Products

by E. Petersen

Modern distribution of frozen fish products

The author describes the important place of frozen fish products in the new marketing techniques that have been evolved in recent years. Modern distribution, with its emphasis on self-service and "convenience" products, has greatly assisted the development of branded goods of a high quality standard; frozen food producers have been aware of this trend and have taken full advantage of it. The importance of attractive packaging, well-directed publicity and careful attention to product quality, as well as the need for constant efforts to develop new products are emphasized.

Les techniques modernes de distribution des produits de la pêche congelés

L'auteur décrit la place croissante occupée par les produits de la pêche congelés dans les techniques de commercialisation nouvelles qui ont été élaborées ces dernières années. Les techniques modernes de distribution, qui mettent l'accent sur le "self-service" et les aliments tout préparés ont joué un rôle important dans la mise au point de produits de marque répondant à des normes de qualité élevées; les producteurs d'aliments congelés ont eu conscience de cette tendance et l'ont exploitée à fond. La communication met l'accent sur l'importance que revêtent un emballage attrayant, une publicité efficace et un contrôle attentif de la qualité des produits, ainsi que sur la nécessité d'un effort constant, tendant à l'élaboration de produits nouveaux.

Despachos modernos de productos pesqueros congelados

Describe el autor el importante papel que los productos pesqueros congelados desempeñan en las nuevas técnicas de mercadeo ideadas en los últimos años. Los comercios modernos, entre los que se destacan los establecimientos que sin dependientes que despachen ofrecen artículos "convenientes", han contribuido muchísimo a la produción de géneros de marca y alta calidad; la industria de los alimentos congelados ha sabido apreciar esta novedad y la explota plenamente. Se pone de relieve la importancia de un envase atrayente, una propaganda bien orientada, un minucioso cuidado para con la calidad del producto y la necesidad de esforzarse constantemente para crear nuevos artículos.

WHAT we call development is a continual change to make life easier, pleasanter and better for the human race. The development of production and sales of all kinds of goods has been proceeding slowly for generations; however, it was not until after the First World War that such development acquired a momentum, which rapidly changed the whole market situation. New concepts of products and their marketing were launched, primarily by the Americans who have been pioneers in the field of production and sales promotion. The growing standard of living in the developed countries led to a large increase in demand for consumer goods of all kinds. Keen competition led firms to introduce new goods, and man's own inventiveness and zest encouraged this trend and led to continual adoption of products. Producers having secured consumer acceptance for their merchandise, saw in the branding of their articles a way to safeguard their place in the market. The rise of branded merchandise created a new theory of consumer goods marketing. Housewives called for high standards of product and service. Moreover, they increasingly demanded ready-packed goods in different kinds of packages of exact weight, and these new demands led to significant changes in retail distribution.

DISTRIBUTION

Retailing

The Americans introduced "supermarkets" and self-service, which after the Second World War have also become common in Western Europe. This system placed a new emphasis on merchandise display and presentation, with goods no longer held in storerooms but presented in a wide range on the selling floor. As a consequence of this practice, selling space had to be extended, and has been steadily increasing.

All merchandise was priced and customers could walk round and choose what they wanted without the help of a shop-assistant and pay for the goods on their way out of the shop. The display of a large range of articles and their easy availability also encouraged sales. The system involved the pre-packaging of merchandise and fitted readily into the branded goods system of distribution, under which the consumer expected a constant and high standard of quality and a readily recognizable package. Producers had to make every effort to keep their products' place on the supermarket shelves—the shops sold space and naturally gave pride of place to the most easily saleable lines. Competition through display and other forms of mass advertising became increasingly strong, and marketing of new products had to be promoted on the basis of extensive market research studies. The function of the traditional market price changed. It became possible and indeed necessary to keep prices fixed during long periods, and this reduced the fluctuations in producers' selling prices which the older traditional system of selling to importers and wholesalers had involved.

Place of frozen foods in modern distribution

The frozen food industry has been quick to take advantage of these new distributive techniques, and in fact was in a very favourable position to do so. The new streamlined distributive process made possible the capital investment necessary for frozen food distribution—the refrigerated cars and lorries for transportation, the cold stores and the deep-freeze cabinets in retail shops. This was something quite new which was not even dreamt of a generation ago. The vital element in the development was to find a way of securing and retaining a high-quality product. As late as just before the Second World War, housewives were delighted when the fishmonger filleted the fish for them, thus saving them the trouble of carrying

the big, wet fish home, and the work of cutting, scraping and cleaning it in the kitchen. New phrases such as "ready to fry" were used, and now a new step forward to the "pre-cooked dish" has been made.

With the improvement in the standard of life in so many countries, domestic habits have changed and have brought about an increasing demand for convenience products, that means products ready to cook, which make the task of the housewife easier and give her more spare time and opportunities to perform other duties, which again can contribute to increasing the family income and its standard of living.

These new developments in shopping habits and preferences, and in the retailing system to meet them, have of course had to overcome the obstacles of tradition and conservatism. It has been said that nobody is so conservative as the housewife when it comes to the question of cooking. While tradition is an important factor in the community, and is to be encouraged in many spheres, particularly the cultural and artistic, it may also hamper commercial development. Many examples can be quoted of countries with traditional trade in various products, falling behind in the modern competitive race for markets through being unable to adapt quickly to new demands and new techniques. My own country missed opportunities in the vast commercialization of winter sports equipment which has taken place over the last years, and in its preoccupation with traditional herring products may also be in danger of falling behind in modern fish marketing developments.

It is clear, however, that modern products are rapidly replacing the traditional products of the fishing industry, and we must be ready to take up new techniques of processing and marketing, and to inform ourselves of modern needs and trends in consumer demand for fish and fish products, so that we can better exploit the resources of the sea.

But, of course, it is not only in Norway that people are bound by tradition in many fields. There are markets with justified demands for traditional goods, but the fact is that the trend both in the western world and in many developing countries is approaching the modern style and taste very rapidly, and in these countries people find the self-service system very attractive. The French proverb: "Il faut un peu de tout pour faire un monde" [We need a little of everything to create a world], can also be applied in this connection.

The movement in the western countries towards self-service has tended to bring about the disappearance of the smaller shops. In Norway, the self-service system has been accepted and has made great progress. There are about 3,000 self-service stores in Norway today. In Sweden the development has been very large and has caused what is called "the death of the small shops". Smaller shops are at a competitive disadvantage, largely through space restrictions. In 1964, 1,400 smaller shops disappeared, and of the 21,000 food stores existing today only 15,000 are expected to be left in 1970. Both in the country and in the towns the decline in the number of small shops and increase in the number of stores with a self-service system is going on. The same development is increasingly apparent in the big Swedish co-operatives. During the last five years the increase of self-service stores in the Federal Republic of Germany has been explosive. In the United States almost all foodstuffs are now sold in supermarkets having self-service.

The catering trade

Great changes are also taking place in distribution to the catering trade, i.e. in deliveries to restaurants, hotels and institutions such as schools, hospitals and prisons. Large-scale deliveries are also increasingly made to factory and business firm canteens and restaurants where meals are served to the staff and this system is developing very fast. Like housewives, institutional kitchen operators are looking for labour-saving products in a ready-to-cook form saving valuable time and labour in preparation and serving. All kinds of institutions are becoming buyers of ready-to-use products, and the sales of branded goods are constantly increasing in the catering trade. The demand of this trade today is for an efficient distribution chain which can deliver ready-to-use products when and where required, and in large quantities. These changed conditions have led to substantial changes in the technique of marketing and in the relative importance of quality and service, rather than of price. In the catering trade, as well as in the retail business, service is so important that buyers are willing to pay for it. In a country where my firm is working, we were once confronted with a competitor who had offered goods at a cheaper price. He was informed that before receiving an order he had to guarantee delivery of a considerable quantity, presented according to the customer's wishes, delivered to his stores, in his packages, and of the varieties he needed, every week of the year. Price was, in fact, a secondary consideration.

MODERN MARKETING REQUIREMENTS

Before the Second World War it was not always easy to sell the big quantities of herring and other fish caught by the Norwegian fishermen. Even today it is questionable whether we make full use of our production chain and sales possibilities to obtain the best possible proceeds from our goods.

There can be no doubt that in the typical export trade for Norwegian fish, modern developments must be given great attention in order to retain our competitive position in world markets. There are, for instance, distinct indications that an ever-increasing part of the fish caught by the fishing nations is being used in the deep-freeze industry, and a corresponding decrease in the quantities used for drying and salting is being recorded. This trend will most likely continue and be acceptable to an ever-increasing number of consumers, since frozen fish has proved to be an excellent ingredient for tasty and nutritious meals. It should be obvious that only by modern marketing methods can this excellent foodstuff be brought to the consumer from the herring and other fisheries in a way that is to the mutual benefit of the fishermen and others in the trade. Modern marketing demands up-to-date production methods, more ready-to-use products, consumer packs, quality control and attractive prices, alike for producer, distributor and consumer.

For these reasons, marketing has become an important subject in the large universities of commercial education which offer marketing courses extending over several years. This only proves the fact that the increasing quantity of articles, the new sales problems, and the production problems have to be dealt with in quite a new way, and given far greater respect and attention than was formerly the case.

The first thing to do if we want to take effective action to meet competition on its own ground is to go into our markets and find out the true situation there. What must we do to provide the housewife in Norway and other countries with all kinds of fish presented in a way that suits her?

If we agree that it is absolutely necessary to keep up with the times and accept the facts of modern marketing, not only to obtain sales today but in order to build up goodwill for the years to come and to be able to adjust for changes in future marketing conditions and play an effective role in meeting them, we must realize what this really means.

First we must have a clear understanding of the fact that modern marketing is far more complicated than business with a chance customer abroad. Under the new world conditions the main principle of our marketing policy should be that we should aim to market our produce as a special commodity, preferably with our own trade mark known all over the world because of the excellent quality it stands for. The above policy must be the basis for our thinking without regard to what kind of article is involved whether it is canned goods, frozen fish or other products from the fishing industry suitable for this modern system of marketing. Much planning will be required and capital will be needed. While many fishing nations are small countries, we must not make ourselves out to be smaller than we are by acting in small units, but rather think in terms of operating through joint or co-operative action to improve our marketing potential and impact.

THE PRINCIPLES OF MODERN MARKETING

The objective of an effective sales policy is to create a profitable outlet for the production, whether of an individual factory or a whole industry. In general, the profitable disposal of a product is more a matter of long-term planning and market development, rather than speculative selling, which sometimes may result in a high price and sometimes in a low price. The producer in the fishing industry is both the fisherman and the factory owner. The most effective system of selling his product is one that constantly secures a good and firm price, which implies regular sales and full utilization of plant capacity. The prime condition for this is, of course, a good product. Furthermore, the product must be regularly available in quantities that ensure a constant supply for purchasers. This means that, for a daily food such as fish, the commodity must be available to the consumer every week of the year.

The adoption of his own trade mark and brand name is of significant assistance to a producer in controlling his own product and developing his business. Extensive works have been written about the sales theory of branded goods, and I shall therefore not go into details here. It is obvious that the ownership of a well-known and trusted brand name is of very substantial commercial value.

The question of the "private label" has been discussed. I think that, as a matter of principle, private labels may be a death line for the producer. He will become dependant on the will of the buyer who is the owner of the trade mark. It takes time and money to introduce a trade mark, but when successfully introduced it is a valuable asset which will form the future basis of your sales, provided you follow the rules. Buyers require a very high standard in branded goods today and producers must always be prepared to comply with the demands of the buyers. A trade mark is of no value unless regular deliveries of substantial quantities can be guaranteed; moreover trade mark publicity is also necessary.

In this connection the supermarket has also a part to play. A modern supermarket or big self-service store does not only sell goods but also "sells space". In an American supermarket it is possible today by means of electronic machines to record day by day the quantity of goods sold and the remaining stock. A product whose sales do not justify the space it occupies in the shelves will be replaced by another branded product which is easier to sell and thus shows the store-owner a more profitable occupancy of space. The owners of the shops do not spend money on advertising. Publicity is the business of the producer. However, once a market place has been secured you will have the advantage of being able to influence sales and revenue to a greater extent than people producing under private labels for a chain business.

In the catering trade, i.e. in the sales of institutional packs, a similar preference for branded and quality-guaranteed produce has taken place. The conclusion, therefore, is that the brand is of very great importance in effective and profitable marketing.

There are always exceptions to the rules, and it is said that "the exception proves the rule"; in periods of scarcity it will always be possible to obtain good contracts under a private label, but these connections will generally be sporadic and sales will normally be effected under shelter of the work done by a big sales organization.

Not all articles are suitable for marketing as branded commodities. There are, for instance, varieties of fish products which should not be marketed in this way. However, it may not yet be fully appreciated that the new forms of retail and catering businesses are determining new production and sales patterns. They have realized that the housewife is, above all, looking for something easy to prepare, easy to serve, and which is attractive and tasty. The producer must, therefore, be prepared to adjust his production and forms of distribution to comply with the housewife's demands, as reflected in the buying policies of the new retail units.

Packaging

These developments in modern food marketing have also shown the need for handy cartons which are suitable for preserving the product and satisfying the demands of the housewife. It is not an easy job to choose the right packaging, however simple it might appear for the inexperienced beginner to make a handsome pack. As a

matter of fact, it is a rather difficult task which calls for a thorough knowledge of modern marketing, knowledge of the article and the countries for which the article is meant, and last but not least the pack must have a design that takes the fancy of the public. Beginners very often make a pack which is only a copy of the packing for a similar article which has already been introduced and is known. It is, however, better to devise a new pack with a design that distinguishes the brand in question from other brands. As a rule, it will be necessary to call in experts trained in this specialized work.

It is very important to compose the right text for the pack. For foodstuffs particularly, the text on the pack must be in accordance with the laws and regulations in force in the country where the goods are to be sold. A good pack is believed to be one of the best means for promoting sales, and it is therefore important that one does not economize unduly on the cost of the pack or on the advice one seeks in developing an original and effective design.

Quality control

To succeed in obtaining regular sales and protect the brand name it is necessary to guarantee first-class quality of every unit of produce. It is not difficult to imagine what the result will be when the housewife buys a package of bad quality. She will react strongly against the brand and may well advise her family and friends against its further purchase. The fishing industry has in the past been careless over quality. The reason may be that the production and processing of fish are carried out in circumstances which are quite different from (and generally more difficult than) the conditions of production of other foodstuffs. However, under modern marketing conditions, an effective quality control system is absolutely necessary on the part of the manufacturer if he is to be assured of a consistently good quality product.

Publicity

When all the above requirements are fulfilled, namely, a regular supply, a brand name, the right pack and high quality, there still remains an important factor, namely the question of publicity to make the brand known. In this field it is easy to fail, either by spending too little or too much. The percentage of selling price applied to publicity to introduce fish products to the housewife under their own label has ranged from 4 to 7 per cent. The Americans calculate 5 per cent. In England the percentage has reached 7 per cent. In other countries it is a general opinion that 4 per cent will be sufficient. It is difficult to arrive at an average figure. The more money the sales manager has at his disposal for publicity purposes the better job he can do, but this expense must be carefully estimated so that it is not in danger of absorbing the bulk of the profit. People are aware of the significance of publicity, but when they reach the stage of having to pay for it they look for someone else to take responsibility. In the fishing industry, for instance, it has often been claimed that publicity for fish should, to a great extent, be paid by the State. All branches of the industry should, however, clearly understand the place of publicity. Personally, I am of the opinion that joint publicity is not very useful. I think we get more for our money when publicity is directed towards a specific brand. Space does not permit the detailing of all the various means of publicity, but it must be stressed that publicity comprises all kinds of propaganda including newspaper, radio and television advertisements, posters, brochures, films, demonstrations and, in many cases, we also have to make use of what are called PR—Public Relations—activities. PR has become an international term which means a company's or institution's relations with the public and the authorities. Information they are able to give concerning their factories, products and sales will, in many cases, be of great interest to the public, and when such information is presented in the right way the resultant publicity may turn out to be much cheaper than expensive newspaper advertising. However, specialized Public Relations activities can normally only be carried on by companies of a relatively large size.

Organization

It is also of great importance in modern marketing to have a marketing and sales organization. The task of this organization is to take charge of the goods between the place of production and the local wholesaler and retailer. This organization is also responsible for the studies to be made of the market. What are the duties of the sales organization? Can it be limited to keeping in touch with agents all over the world, or should it have a certain number of subsidiaries in several places? What does the expression "sales organization" really stand for? A sales organization must generally involve having more than connections or agents at particular locations. It should consist of its own employees, or selected agents under its control and direction. It must be efficient in its organization of product distribution and have direct control of such distribution right to the retailer. There are, of course, general market circumstances, for example the basic demand of housewives for the intrinsic qualities of frozen fish products which the sales organization cannot influence. But the conditions prevailing in the distribution of the product between factory and the consumer ought to be controlled by the sales organization. However pretentious it may seem, a processor should control his product's distribution and presentation to the final point of sale and be able perhaps to influence and fix the price. Local distributors, wholesalers and retailers, have their own standards and get their commission. Conditions differ in the various countries; in the large markets it is very expensive to attain such an objective. Even there, a sales organization, if fully effective, must be in a position to make the decisions on the retail marketing of the products for which it is responsible.

It goes without saying that modern marketing with all the requirements mentioned above needs a considerable amount of capital to be effective, and this is beyond the reach of small manufacturing concerns. Very few single producers can manage this task. How big the organization should be is a matter of evaluation, and it is impossible to lay down standards. In the American market for frozen fish, a sales organization would have to offer sufficient quantities to maintain a regular supply. A sales system in the larger countries of Western Europe would also have to guarantee a regular weekly supply if it hoped to be successful.

One of the most important interests of the fishing industry is to secure regular sales of the product which tens of thousands of fishermen haul out of the sea. It is a great responsibility to provide the very best way of selling these products. It is our duty to move with the times so that people can continue to live on the coast and work there under the same conditions, with the same wages and social advantages as people working in other industries and in other places. The aim must be to help the fishing industry to become as self-supporting as possible.

PRODUCT DEVELOPMENT

I have not yet talked about the production process. It is a common practice to mention production first and then sales but I have done it the other way round because I think we ought to adapt production to sales requirements. The factories must produce the goods wanted by the various markets. It is useless to make a series of products and instruct the salesmen to sell them. The retailers must tell the producers what products they require.

We know that the most important thing for the producer of foodstuffs to take into consideration today is the fact that the article has to be easy to prepare. There is an increasing demand for ready-to-use products. We have expressions like "ready-to-cook" and "fish portions". We have seen that great changes have taken place in the production of fish products. There are distinct indications that the quantities of fish used for salting are constantly decreasing. The products wanted by the housewife today are those that make her task in the kitchen easier than before. This trend calls for a continuous development of new products. How can we develop new ready-to-use products which are easy to sell at a good price?

The development of new products is of vital importance. This may cover a wide field from research work to practical inventiveness in trial kitchens. In any case this work requires money and people specially trained for this purpose are necessary. Each producer cannot manage this task alone. It is a question of study, and a precondition for this is the right understanding of market needs and trends. In order to understand the possibilities of development of new products, it is necessary to follow the development in the markets. It is a matter of finding out what each market wants and not to take it as a matter of course that people in other countries have our own tastes. The development of new products must be initiated by people engaged in marketing work. It is a part of marketing work to provide information and new ideas which can be tried and worked out by the producers. Sometimes it happens that some ingenious producer invents a new product which turns out to be a great success, but if this work is to be systematized, producers must try to make it a regular task, employing people specially trained for the purpose. Market analyses and tests will be necessary to develop products that people in the various markets will want to buy regularly. People engaged in the development of new products must keep in touch with the sales department. Development work may, of course, require larger concerns to meet research costs, but effective development work can also be carried out by independent institutes working in close co-operation with leaders of sales organizations. There are many possibilities in the new products development field that people do not even dream of. Orange production in the United States is an example of what can be done. The American producers were facing the problem of over-supply and solved it by the development of a new product —frozen concentrated orange juice. This was a new method of providing consumers with a concentrated orange juice that had the same fresh taste and the same vitamin content as fresh oranges, a product which could be stored during longer periods and transported over greater distances without deterioration. Today many families in America drink this juice every day, and there are no longer problems of over-supply in American orange production.

The fishing industry has also been trying to persuade people to eat more fish. In the United States, one of the largest food companies, General Foods, worked on the problem but from a different angle than before. They developed a new product from fish which had been frozen into blocks, and today this new product, pre-cooked, breaded fish portions of various sizes, is called "fish sticks". In the course of 10 years this invention has caused a revolution in the sales of fish in the United States. Today 90,000 t a year are sold there, and sales of this product are increasing rapidly in Western Europe.

This is striking proof of the fact that development of new products is likely to be a very important factor in the fishing industry. Nobody can convince me that nothing can be done with the herring and abundant mackerel. We are on the threshold of a great expansion in the production and sale of pre-cooked products—in this connection electronic ovens are of significance—and we may expect developments in the catering trade which we did not dream of a few years ago. Great demands will be made upon producers, organization of development work in the different sectors of the industry will be necessary, and this calls for capital and proper realization of the opportunities arising from co-operation between the various branches of the trade.

CONCLUSIONS

We have to face the fact that the development of the retail trade is proceeding rapidly towards bigger self-service stores directed and controlled by large concerns, and that the demand of the retail and catering trades will be for ready-to-use products packed in handy cartons and of a uniformly high quality.

These demand requirements necessitate increased efficiency in the field of both production and sales if the fish trade is to take advantage of them and retain its competitive position.

The development of new products must be the common concern of each sector of the industry and must be carried out by people specially trained for this purpose. These people must have the opportunity to work in close co-operation with people dealing with marketing and sales. Finance should be no problem if there is a right understanding of the significance of new product development in the future progress of the industry.

Sales must be arranged by organizations having sufficient funds to carry through a rational and effective sales promotion programme. There are many forms of sales organizations, but whatever its form its main objective must be co-operation with the other sectors of the organization. The whole organization must be considered as one unit comprising the specialized departments of production, control, finance and sales. The consumer is the final arbiter, so that the sales operation is the main factor serving to guide the decisions to be taken by the other departments.

DISCUSSION

van Meir (U.S.A.): It seems that during our previous deliberations we have tended to view freezing as a single purpose technology. However, freezing is actually used to meet a number of different problems and the considerations are quite different in each type of application. For example, there is the problem of the seasonal pattern of landings, where freezing enables fish to be directed from the market at the peak of seasonal landings, to the season of low landings. Secondly, in other instances, freezing has been used to increase the proportion of fishing time to time at sea when vessels have had to go greater distances for fish. Finally, perhaps we are eventually looking for a freezing technology that will enable frozen fish to re-enter the market at the retail level as virtually fresh fish.

Bahr (Federal Republic of Germany): In spite of the increased landings of sea-frozen fish during recent years, the landings of wet fish, including those of the sea-going trawlers as well as those from the coastal fishery, remain important in the promotion of increased fish consumption.

There is frequently a surplus of fresh fish at the auction because unpredictable weather and fishing conditions make it impossible to balance the supply with the market demand. A surplus in the supply of wet fish is usually seasonal and is not directly dependant on overall yearly landings. For example, the wet fish landings from high seas trawlers of the Federal Republic of Germany decreased from 261,000 t in 1962 to 175,000 t in 1966. Nevertheless, during the first six months of 1967 10,300 t of wet fish remained unsold at the auctions in the four principal landing ports and could only be utilized in the production of fish meal. Similar situations have been reported from other west European countries.

Surplus landings, which occur almost exclusively during the hot months, represent an economic risk to the wet fish fleet and this risk mainly accounts for the decreased landings of wet fish in the Federal Republic.

Loss in proceeds through a surplus at the auction could be reduced by freezing the extra supply and selling it at reasonable prices. Of course the freezing should take place immediately after the auction and only high quality wet fish should be frozen. If this is done and the cold chain maintained, fish which is frozen ashore may well reach the consumer in better condition than chilled fish which has undergone transportation that takes longer than one day.

Freezing the surplus supplies at the auctions will not only assist in balancing supply with demand, but will also lead to a stabilization of market prices, which in turn will have a good effect on consumer demand.

While there is a steadily increasing demand for sea-frozen fish and fish fillets on the markets of the Federal Republic of Germany, no significant market has yet been developed for similar products frozen in shore plants.

Marketing of sea-frozen fish in the Federal Republic is usually done through the food retailer and not the fishmonger who, with few exceptions, restricts his stock to iced fish, smoked fish, canned fish and the like. Efforts now being made to interest fishmongers in the sale of shore-frozen fish will likely be successful because these products more closely resemble chilled fish than sea-frozen fish in taste and quality. In this connection, it might be mentioned that fishmongers are not interested in sea-frozen fish because, they say, it lacks the typical "sea fish" flavour.

The advantages and possibilities of utilizing, through freezing, the wet fish surplus at the auction should be recognized in any future formulation of international codes of practice for frozen fish.

Holliman (FAO): I think that van Meir and Bahr have touched on a very important point which concerns the facility of the frozen product to enable the supply to be spread over time. On the face of it, this appears to be an advantage, but I also believe that, in recent times, this has caused some anxiety and some problems of its own from an economic point of view, in the sense that the presence of relatively large stocks of frozen fish available for distribution and sale has, in itself, had a somewhat unfortunate effect on the operations of the traditional wet fish producers. It would be useful to hear from any delegates who have had experience of this problem and how they see this matter developing in terms of the economic implications of large buffer stocks of frozen fish available in or near the ports of landing of wet fish.

Butcher (OECD): Several references have been made to the use of freezing as a means of preserving surpluses for use in times of scarcity. In theory, this seems to be a reasonable proposition but, in practice, the costs involved and the timing difficulties present considerable obstacles. Another consideration relates to the desirability of freezing surplus fish that has not found a buyer on the open market. Such fish, or part of it, may not be of high quality and would therefore not result in a good frozen article.

Ranken (Spain): On the question of surpluses, no one who had seen the quality of most of the genuine surplus distant water fish on the markets in Bremerhaven, Hull or Grimsby could possibly contemplate freezing it. This was the worst fish, and if it was unsaleable when fresh, it was bound to be worse after freezing. Freezing could not improve quality, but only retard further deterioration. Freezing of surplus fish has retarded consumer acceptance of frozen fish by at least ten years in some countries. Freezing of these surpluses must not be confused with the perfectly reasonable purchase of top quality wet fish on the market for processing and freezing into consumer packs. Torry recommends a delay of not more than three days for freezing at sea, but considers a delay of up to nine days as quite acceptable for shore processing and freezing as practised by several of the larger companies.

Sutton (U.K.): There is at least one company in the United Kingdom which buys fish when there is an excess on the market and maintains a buffer stock of frozen fish. In the case of cod, only certain fractions, namely the high pH fish, are suitable for cold storage. We are working on a system for grading the fresh fish (three to eight days old in ice) according to the muscle pH, as it arrives at the factory and only the high (>6.8 pH) and possibly the medium (6.4 to 6.8 pH) will be used for cold storage and the low pH fish will be distributed immediately.

Heen (Norway): I would like to follow up remarks made concerning the principle that frozen fish should enable us to even out supplies to give a fair balance between consumption and production. In practice, it doesn't work out as simply as that. I have been wondering to what extent it has been found in various countries that sea-frozen round fish is entirely

interchangeable in trade with a similar species as wet fish, and in that case, does it follow the same distribution channels and regularly sell to either the housewife or the fishmonger for a lower price than similar wet fish. I believe, in fact, that the frozen fishery product is a different article and not interchangeable in trade with the fresh fish. It follows different channels and is viewed differently by the consumer. It is the convenience of frozen packaged fish that is perhaps most attractive to the buyer in some advanced industrial communities.

There is another point. I have been quite amazed that it hasn't been possible to have some kind of an international consultation on the marketing side of fisheries. There is no other marketing activity that I know of, which calls more for international consultations. The substantial volume of frozen fish landed from the vast freezer fleets last year have influenced the fish trade in other channels. These stocks of frozen fish from the freezer fleet, which amounted to about 300,000 t in 1966, had a very great impact on the trade in salted and dried fish because they affected the market for frozen fillets. This tended to influence the coastal fisheries and fish processing plants to turn their production into dried and salted products instead of frozen fillets. This, in turn, had a great repercussion on some of the established markets for dried and salted fish. So it seems that the interchangeability is much broader than just between frozen and wet fish.

Fernández y Fernández (FAO): Me voy a referir a algunos aspectos prácticos y económicos que pueden ser de utilidad a la Conferencia. Voy a tomar como base dos países que conozco un poco: Argentina y España.

En Argentina, por ejemplo, se produce el hecho que comentaba el Sr. Holliman, de que el mar próximo está lleno de pescado, pero sin embargo los costos de producción son altos, a mi juicio por las siguientes razones: el costo operativo de la flota podemos señalarlo en un índice de 10, pero en cambio los gastos de tráfico y comercialización hay que señalarlos con un índice de 30. Aunque capturar el pescado no costara nada y fuese un regalo, los gastos de tráfico y comercialización son permanentes y por lo tanto resulta imposible reducir en forma importante el costo de la producción. De otra parte al tener la pesca muy próxima, se realiza una captura muy descuidada en el aspecto tecnológico y sanitario. Eso hace que el público (tradicionalmente consumidor de carne) siga despreciando permanentemente el pescado. La solución al caso sería introducir el congelado en estos países poco desarrollados para incorporar al costo operativo en la mar el costo de la operación de congelación suprimiendo de un plumazo todos los gastos del tráfico portuario, que evidentemente destruyen o neutralizan el esfuerzo. A mi me parece que se generaliza demasiado al hablar de congelado frente al pescado fresco. El congelado es un sustitutivo, nació por una necesidad. Si por un fenómeno inesperado los caladeros de Europa se llenasen de peces todo el armamento de congelado se vendría completamente al suelo. Por ello, a mi modesto juicio, hay que tratar separadamente un hecho de otro y pensar siempre que el congelado es un complemento, en el volumen y en la magnitud de la reducción de las capturas de las especies que están próximas a la costa o a distancia media.

En España, que es el único país a que me quiero referir, la pesca costera nunca necesita congelar; por ello, cuando se habla de congelar en tierra se dice algo que no tendría aplicación más que en algunas producciones especiales como el atún, que puede congelarse en las fábricas de conservas para un enlatado más lento y ordenado. En la distancia media, que son las capturas que llamamos nosotros del Grando Sole (S.W. de Irlanda), tampoco es necesaria la congelación porque está probado a través de 40 años que con los 12 ó 15 días de la expedición en hielo se conserva perfectamente. De modo que la congelación está únicamente indicada para las distancias grandes. En consecuencia, el hecho económico de congelado es distinto y debe examinarse y tratarse de una forma totalmente separada y no en oposición o competencia. Conservar en hielo o congelar a bordo son operaciones impuestas por factores de abundancia o distancia. En tierra sólo debiera congelarse excepcionalmente.

Decía el Sr. Holliman que el mar está lleno de peces, pero que sin embargo el mundo sigue con sus problemas de alimentación y disponibilidad de esas existencias y que los países no los capturan porque no saben qué hacer con ellos. Esto se debe, en mi modesto juicio, a la falta auténtica y real de cooperación internacional. A los países en desarrollo les frenan su expansión pesquera en sus propias costas, los desarrollados, que con sus flotas capturan lo suficiente para no sentir necesidad de comprar a los países ribereños.

Estamos en una Conferencia patrocinada por la FAO, cuyo lema y emblema es atender los problemas de alimentación del mundo. Termino diciendo que mientras no se tomen en serio, mediante conferencias que regulen la explotación de los recursos, que los cuiden, que los distribuyan sin daño para nadie, se perderá lamentablemente el tiempo y unos seguirán pescando de un modo y otros de otro, pero la humanidad seguirá igual, sin resolver los problemas del mar en forma ordenada y eficaz. Una Conferencia patrocinada por FAO, con pocos discursos, donde los biólogos, psicólogos y economistas aborden seriamente los problemas, con todo rigor, científico, político y económico, puede ser la solución y al menos, es la única solución a intentar.

Darghouth (Tunisie): Le poisson congelé doit-il constituer un stock régulateur ou ne doit-il être qu'un appoint par rapport au poisson frais?

Il semble qu'il faille examiner les tendances des pays pris individuellement, ainsi que certaines espèces prises dans l'ensemble d'une économie de marché. (Par exemple, la Tunisie a intérêt à importer du thon congelé du Japon pour son traitement dans les usines de conserves—complément par rapport à la production nationale du thon rouge—elle a aussi intérêt à vendre du poisson frais par avion cargo à l'Italie. Ce poisson y est très apprécié et vendu très cher.)

La FAO, dont le rôle est d'étudier et de régler dans la mesure du possible les problèmes alimentaires ne pourrait-elle mener une enquête afin de déterminer les tendances de consommation de poisson dans les différents pays, ainsi que leurs besoins et leur production dans cette denrée principle, si riche en éléments essentiels. Cela aiderait tant de pays et principalement ceux en voie de développement.

Rudolphi (Federal Republic of Germany): I have heard the comment that, in Germany, we prefer frozen fish. Now let us not make any mistake—there are two distinct lines of distribution in Germany, one for fresh fish and the other for frozen fish. Frozen fish has added to the opportunities in fish marketing but as Bahr has just mentioned, the traditional fishmonger does not handle frozen fish in consumer packs. He doesn't like it because the margin, especially for the brand names, is not as good as the margin on fresh fish. So we cannot say the German consumer prefers one or the other. They are distinctly different products as far as marketing is concerned.

The main interest of the German sea freezing industry is fillet blocks. Single frozen fillets are becoming important, but for the time being the blocks are our bread and butter.

There are many problems connected with this type of production. Most of them are dealt with admirably in the papers presented during this Conference, so I just want to point out a few major ones that are adversely affecting the whole business: What we need most are internationally standardized block-measurements fitting into the accepted pallet-modules. The vast differences in size and weight prevent

the trade in fillet blocks from becoming truly international, and severely handicap both the producer and the buyer.

The packaging material for the blocks is frequently a nuisance. On some days, four to five men are needed to free the blocks from paper and cardboard quickly enough to keep up with the sawing crew. I know three types of packaging: one that becomes frozen to and between the fillets, and has to be scraped and pulled off by force; one that comes off so easily that some of the blocks are naked on arrival at the plant, and one that preserves the quality very well and is easy to remove but causes the block to have one or two round edges which mean trimming losses.

My proposal is to containerize unpackaged blocks which have plastic sheets interleafed. Of course, the containers must be airtight. They can be rather large, since they have to be moved mechanically anyway. They can be filled right out of the freezer, and the blocks can remain in them during storage in the ship and on land until they are processed. Containers like this could be used with existing pallet-pods. They would eliminate not only our packaging problems, but also the disorder that occurs on most fish piers where frozen fish is unloaded. But before this, we need international block standards. I think this must be done very soon before the different groups that are working on their own standards definitely decide on their own sets of measurements.

Ranken (Spain): I would like to strongly support Rudolphi in his plea for standardization of block sizes, packets, cartons, etc. Not only would this have a fundamental effect on the costs of much of the handling and processing machinery, but in conjunction with correct dimensioning it could have a great effect on stowage plans, hold size, hatch dimensions, freezer layout and size, tray dimensions, freezing times and many other details throughout the handling chain. If airtight containers could be used, it would eliminate the need for packaging of fillet blocks, but conventional containers involve a considerable logistic problem in returning them empty to the ship, especially if transhipments are involved. It might be possible to devise cheap disposable containers which do not need to be returned. As a principle, the largest and most compact stack of blocks which could be handled conveniently would be the best choice.

Kreuzer (FAO): Another important problem facing the fish freezing industry concerns deeply-ingrained consumer preference for particular species or particular types of product. As an example I might mention the Mediterranean area where the consumers like the small red-coloured species. The Greek freezer fleet has been taking and freezing such fish off Mauritania and they are sold in the markets of Greece alongside fresh fish of the same species but at half the price. The Greek fleet now finds it difficult to meet the demand since the Mauritania grounds are not very rich. Some vessels are therefore going to South Africa after hake or to the other Atlantic waters where they take dark-coloured species with which the consumer is not familiar. The successful introduction of these products on the market will require efforts which, in some cases, may be beyond the capabilities of the fishing industry by itself.

In Israel the consumers also like the red-coloured fish, but their vessels are now fishing in the Red Sea and Indian Ocean where they take black-coloured species which the consumers are not willing to buy. This is a matter of grave concern to both the industry and the government.

In Italy there is a different problem. The Genepesca has tried to introduce frozen fish from the North Atlantic and there is no difficulty as far as species is concerned. However, the Italian consumer considers frozen fish to be inferior and the industry left the sale completely in the hands of the fishmonger. The result has been that fish which bring the vessel owner 200 lire are offered in thawed condition in the fish markets for between 700 and 1,400 lire. Such a price situation prevents further development in the fish freezing industry.

O'Sullivan (Ireland): After hearing the various speakers deal with the difficulties facing the industry and in particular the technologists, in ensuring that frozen fish products reach the consumer in, what one might call, perfect or near perfect condition, I cannot help but feel that as technologists we may be striving after a perfection which may not be achievable in commercial practice. The time may well have come to have a close look at whether we are concerning ourselves over-much with a preservation technique rather than with products, based on a completely new development approach, which can be more efficiently handled in the frozen chain. We should have a really fresh look at the whole idea of frozen foods, rather than continuing to criticize the industry for failing to meet the very high standards which we, as technologists, like to set for near-perfect preservation of seafood products as we now know them.

Lloyd (U.K.): I appreciate that the following comment is out of context in relation to the precise title of the conference. However, it is of such importance to the long-term economy of fishing industries that it must be mentioned. The fundamental factor of supplies has received scant mention. I refer to the embryonic problem of decreasing catches coupled with quality and to the overfishing of highly productive areas. It has been admitted that information on catching rates is negligible. I suggest, therefore, that the interests of the fishing industry would be better safeguarded by balancing the truly long-term investments, which must be taken to include research into catching rates and above all conservation, against the much greater cost of freezing apparatus. For this purpose, the latter may be considered a short-term investment, and considering the cost differential the dividends can in no way be compared. Since the ultimate survival of the fishing industries depends on this research, it is of extreme importance that they co-operate to the full with their governments' research organization, both in the technical and financial field.

It is already time for the fishing fleets to begin to farm and conserve their raw material, rather than remain at the level of primitive trappers with high-cost, sophisticated equipment.

Slavin (U.S.A.): In his paper, Rasmussen clearly points out the type of information required to properly assess the merits of freezing. Our dilemma is that we do not have sufficient data. Papers submitted by the economists here lack the marketing and cost data necessary and deal more with philosophy than with facts. As a positive suggestion, I would like to propose that FAO consider holding a conference on economic considerations in utilizing and developing fisheries.

Butcher (OECD): In view of the suggestions for various types of economic investigations I would like to mention the following studies to be undertaken by OECD in 1968:

(1) Costs of freezing at sea and on shore. This would more or less involve applying money values to the processes listed in the paper by MacCallum and Sepic.

(2) International production and marketing of frozen fish taking in productive capacity, market evolution, price determination, assessment of holdings and the interchange of market intelligence.

(3) Packaging materials, particularly plastics and their suitability and application in the fishing industry.

Holliman (FAO): We all heard with interest the work that OECD is planning to do in this field and I think that perhaps this leads us logically to the question concerning the dearth of existing statistics in regard to catching, marketing and distribution and to whether we can suggest any ways in which this can be overcome for the benefit of all countries who are

interested in development in this field. I think also it is worth mentioning the point raised by Fernandez this morning about the need for the proper use and the proper conservation of resources. In his statement at the opening of the Conference, Harrison mentioned that this was a field in which FAO would almost certainly find itself more and more involved over the next few years. This question of the management, conservation and proper use of resources is almost certainly going to need, certainly at the national level and probably at the international level, far more information than we have at the moment about the relative cost structures of the present operators in the various sea areas with which we shall be concerned. This is going to be a problem for administrators and economists in which they are going to get very deeply involved as to exactly how some catch restriction may be brought into effect in certain over-fished waters. It is clear that, in order to do this effectively, each national administrator will need to know at least the basic facts concerning his own fleet and industry cost structure. My own feeling is that even nationally a great deal of this information is unknown at present.

Harrison (FAO): I might just follow up a little on what Holliman has said. Earlier, Heen mentioned that one of the advantages of freezing at sea was the mobility of the fleet, and that if the fishing got poor on a certain ground they could move some place else. This has another aspect and relates to the point that Fernandez made, and in which we in FAO also have an interest. The mobility of the large fleets now in existence can have a dangerous aspect because they may possibly move in on a stock of fish and fish them to a dangerous level before there is opportunity to measure actually what is going on. So, we in FAO have a number of interests in what is being made possible by the great expansion of freezing at sea.

I might mention also that, at the present time, FAO is carrying out a major exercise, called the Indicative World Plan for Agricultural Development, which involved the whole Organization. The objective of the plan is to delineate the possibilities and problems of meeting the critical food situation in years to come. The target dates selected are 1975 and 1985. In the course of the exercise, projections are being made of the probable food demand, based on estimated population increase and economic growth. We in the Department of Fisheries have the problem of looking ahead to estimate just how much fish will be able to contribute to meeting this food demand. There are a number of very difficult problems because we not only have to consider what can be produced and the probable investment costs that are going to be involved but also the state of flux the fishing industry is in at the present time. The industry is developing so rapidly that it is very hard to look ahead. It is difficult to predict what will happen in the next 15 or 20 years on the basis of what has happened, say, in the last 10 years. How and where are fish going to be caught in the next 20 years? The stocks of most of the preferred species are now being heavily fished. If we are to keep on increasing production of fish to help meet the food demand, we probably will have to increasingly utilize what are now considered to be the less desirable species. These, in many instances, are in more distant waters, at least from the home ports of most of the nations having highly developed fishing industries. We are, therefore, very much aware of the gaps in our knowledge at the present time and consider meetings such as this and discussions such as have been going on here today to be very useful.

In as much as we also have to think in terms of 10 to 20 years hence, I wonder if some of the discussion today has not been influenced by our viewing problems too much in the present. I believe that it is quite generally accepted that frozen fish is going to become increasingly popular. I think marketing is going to change. In the United States practically all the food shopping is done in supermarkets. Supermarkets are expanding in France, in Italy and in the United Kingdom. This is going to bring about an entirely different approach to marketing. Thinking in terms of 1985, one need not be much concerned about what the fishmonger thinks today because perhaps the fishmonger, as we now know him, will not be in business in 1985. In considering the long-term view, we should not base what is going to happen in, say, 15 or 20 years on just exactly what we are doing today.

Fernández y Fernández (FAO): El tema de la evaluación y conservación de los recursos es importantísimo y si no se toman medidas urgentes todos los esfuerzos técnicos desarrollados o en desarrollo, tendrán que abandonarse por falta de materia prima, al menos mientras no se utilicen nuevas fórmulas de captura que permitan trabajar en mayores fondos y caladeros muy conocidos.

El gran triángulo de la producción pesquera mundial fue Europa, Africa y América del Sur (además de las zonas bacaladeras del Artico, Terranova, Labrador, etc.); pues bien, hoy Europa tiene sus caladeros devastados sin que hayan servido para nada las conferencias en las cuales se tomaron acuerdos muy importantes para el empleo de redes adecuadas, tallas de peces, etc. Todo quedó en nada y entre unos y otros se agotó la zona europea de pesca. Al final de la última guerra mundial, se comprobó que la capacidad reproductora de los bancos europeos es extraordinaria pues después del conflicto, debido a las vedas forzosas, se encontraban de nuevo repletos, con un rendimiento extraordinario para la industria y el abastecimiento. Si Europa quisiera, si sus Gobiernos y pescadores se pusieran seriamente de acuerdo, probablemente se auto-abastecería el mercado de Europa sin necesidad de grandes desplazamientos a otras zonas. En Africa y refiriéndome concretamente a la pesca de la merluza en la zona sur y tropical, al iniciarse la pesquería por la flota congeladora española (1961) había un índice de rendimiento por unidad de esfuerzo que señalaremos en 10; hoy está rindiendo no más de 3 ó 4 números índice y con perspectivas mucho más sombrías a medida que nuevas flotas y nuevos aparejos entren en acción. En América del Sur existe desde Brasil a Tierra del Fuego una meseta sumergida de grandes posibilidades y que apenas fue explotada por las flotas de aquellos países a causa de que—en general—no son pescaderos, sino carnívoros y no entendieron el aprovechamiento de sus recursos en forma intensiva. Pues bien, mientras esto ocurre, flotas de otros países practican una pesca que producirá fatal e inevitable el agotamiento, en mayor o menor grado de aquellos bancos. Este hecho produce la natural y justificada irritación de los países ribereños. En resumen, dentro de pocos años, Europa, Africa y América habrán dejado de ser focos de producción pesquera importantísima con el natural colapso económico para las grandes flotas y para los pueblos que consumen los millones de toneladas de pescado allí capturados. Es por ello por lo que me permito proponer a la Conferencia el acuerdo de sugerir a la FAO que lleve a cabo la convocatoria de una gran conferencia mundial para la evaluación y conservación de los recursos marítimos. Pero no una conferencia donde unos y otros pronunciemos lindos discursos, sino donde economistas, sociólogos, políticos, etc., trabajen sobre el inventario de los recursos pesqueros y promuevan su explotación económica en bien de la humanidad. El Sr. Harrison dijo que para 1975 es la fecha en la cual la crisis de alimentación humana alcanzará su grado mínimo. Pues bien, me permito profetizar que si no se toman medidas urgentes en 10 años no habrá nada que distribuir y en vez de la conferencia que menciono habrá que convocar otra para ver qué se hace con los cientos de barcos magníficos, modernos, que estarán arrumbados en los puertos por falta de pescado en los mares.

Primeras Experiencias en la Congelación y Mercadeo de Filetes de Pescado en Peru

por J. Basadre

Primeras experiencias en la congelación y mercadeo de filetes de pescado en Peru

Describe el autor varios de los problemas encontrados, y de las soluciones prácticas aplicadas, en la producción comercial y mercadeo de filetes de pescado congelados en el puerto de Paita (Perú).

Debido a las peculiares condiciones de la pesca en el país, escasean los medios para manipular y refrigerar el pescado a bordo.

El fileteado se realiza a mano en tierra. Para congelarlos, los filetes se colocan en bandejas de acero inoxidable de 0,5 kg (1,1 lb) de capacidad para paquetes individuales o de 5 kg (11 lb) para el mercado de instituciones, que se disponen en congeladores de placas horizontales. Como el tiempo medio que requieren para la congelación las diversas especies que se filetean varía mucho, es importante que al proceder a congelarlos no se mezclen en la misma partida filetes de diferentes especies. Se indica el rendimiento de las especies empleadas.

Los bloques de filetes congelados se envasan en bolsas de polietileno imprimido que se ponen en cajas de cartón ondulado y se envían a Lima (1.250 km, 750 mi) a través del desierto, en camiones isotermos de 15 m³ (530 ft³) de capacidad que transportan 6 t de filetes congelados. Debido a la frecuencia de las averías del sistema de refrigeración mecánica causadas por la arena que obstruye los condensadores y a la elevada temperatura exterior [34°C (93°F) a la sombra] se comprobó que era preferible emplear hielo seco en la proporción de 5 kg de éste por m³ (0,3 lb/ft³) de capacidad de la caja aislada del camión.

El mercadeo del pescado congelado ha estado obstaculizado por la falta de pescaderías y de medios de exhibirlo. Sin embargo, con las 200 t de filetes congelados vendidas en el primer año de operación, de las cuales el 55 por ciento se colocaron en el mercado al por menor y el 45 por ciento en instituciones, puede considerarse que ha tenido éxito la introducción de productos pesqueros congelados.

First experiences in freezing and marketing fish fillets in Peru

This paper describes some of the problems encountered, and the practical solutions adopted, in the commercial production and marketing of frozen fish fillets in the port of Paita (Peru).

Because of the fishing conditions peculiar to the country, fish handling and refrigeration facilities on board vessels are rather poor.

The fish filleting is done by hand on shore. For freezing, the fillets are placed in horizontal plate freezers, in stainless steel freezer trays holding 0.5 kg (1.1 lb) of fillets for convenience packs or 5 kg (11 lb) for the institutional market. As the average freezing times of the various species used for filleting vary considerably, it is important that fillets of different species are not mixed in the same freezing batch. Yields of the species used are also indicated.

The blocks of frozen fillets, packed in printed polyethylene bags and cased in corrugated cartons, are transported to Lima (1,250 km, 750 mi) through a desert area. Transport is by insulated trucks of 15 m³ (530 ft³) capacity, carrying 6 t of frozen fillets. Because of the frequent breakdown of the mechanical refrigeration system, due to obstruction of the condensers by sand, and the very high outside air temperature [34°C (93°F) in the shade] the use of dry ice was found preferable, in the ratio of 5 kg dry ice per m³ (0.3 lb/ft³) of insulated truck body.

The marketing of frozen fish has been hampered by the lack of retailing and display facilities. However, with 200 t of frozen fillets sold during the first year of operation, of which 55 per cent were in the retail and 45 per cent in the institutional market, the introduction of frozen fish products can be considered successful.

Premiers essais de congélation et de commercialisation de filets de poisson au Pérou

La communication décrit certaines difficultés rencontrées et les solutions pratiques adoptées en matière de production et de commercialisation de filets de poisson congelés au port de Paita (Pérou).

Du fait des conditions dans lesquelles la pêche est pratiquée dans le pays, la manipulation et la réfrigération des prises à bord ne s'effectuent pas de façon très satisfaisante.

Le filetage se fait à terre, à la main. Les filets sont congelés au moyen de congélateurs à plaques horizontales, dans des plateaux d'acier inoxydable renfermant 0,5 kg (1,1 lb) de filets pour les emballages "tout prêt", ou 5 kg (11 lb) pour l'alimentation des collectivités. Etant donné que la durée moyenne de congélation des diverses espèces filetées varie beaucoup, il est très important de ne pas placer dans le même lot des filets d'espèces différentes. La communication indique les rendements des espèces utilisées.

Les blocs de filets congelés, emballés dans des sachets de polyéthylène imprimés et rangés dans des boîtes de carton ondulé, sont transportés à Lima (distant de 1,250 km, 750 mi) à travers le désert, par camion isothermes d'une capacité de 15 m³ (530 ft³), portant chacun 6 t de filets congelés. Etant donné les pannes fréquentes du système de réfrigération mécanique, dues à l'obstruction des condenseurs par le sable, et la température extérieure très élevée [34°C (93°F) à l'ombre], on a jugé préférable d'employer de la glace carbonique, à raison de 5 kg par m³ (0,3 lb/ft³) de volume de camion isotherme.

La commercialisation du poisson congelé a été handicapée par le manque de magasins de détail et de meubles de vente. Cependant, avec l'écoulement de 200 t de filets congelés la première année, dont 55 pour cent sur le marché de détail et 45 pour cent sur le marché des collectivités, on peut considérer que la lancement des produits de la pêche congelés a réussi.

DURANTE el año 1966 se han efectuado las primeras experiencias comerciales en el Perú, de fileteo y congelado del producto de diversas especies de pescado para su venta en el mercado interno del país. Estas experiencias se han realizado en el puerto de Paita, situado sobre el Océano Pacífico en la costa norte del país (05° 03'S).

La empresa que ha efectuado este trabajo cuenta con una planta de fileteo a mano y una congeladora a placas Atlas PFU-2 y durante el año 1966 ha procesado 889 t de pescado en bruto, produciendo 221 t de filetes que han sido enviados a los mercados del país. Las principales especies trabajadas fueron: Lenguado (*Paralichthys adspersus*), Toyo (*Mustelus* sp., principalmente), Coco (*Paranlonchurus peruanus*), Merluza (*Merluccius gayi peruanus*), Cachema (*Cynoscion analis*) y Congrio (*Genypterus maculatus*). Todas estas especies son abundantes en la zona norte del Perú en donde se capturan con redes de arrastre.

Gran cantidad de pescado capturado no tiene colocación en el mercado, como en el caso de la merluza que en su mayor parte es utilizada para la fabricación de harina de pescado. No es raro obtener capturas de 30 t de merluza en un día con embarcaciones de 17 m (56 ft) de eslora.

FACTORES QUE INFLUYEN EN LA PRODUCCION DE FILETES DE PESCADO CONGELADOS

Debe notarse que a pesar de la gran cercanía al Ecuador, las aguas costeras del norte del Perú están aún influenciadas por la fría corriente costanera del Perú. La temperatura superficial oscila entre los 12° y los 23°C (54° y 73°F), presentándose temperaturas más bajas durante los meses de mayo a noviembre y más altas entre diciembre y marzo, meses en los que se produce una invasión de aguas cálidas.

Prácticamente toda la pesca desembarcada por el puerto de Paita proviene de una estrecha faja de plataforma continental, ubicada entre Punta Pariñas y Punta Aguja, con un largo total de 85 millas y un ancho variable que llega a tener un máximo de 25 millas frente al Golfo de Sechura. Es así que toda la pesca que se desembarca es obtenida durante el mismo día, ya que la corta distancia a las zonas de pesca hacen innecesarios los viajes más largos.

El tipo de embarcaciones utilizadas actualmente no cuentan con sistemas especiales para la conservación del producto, aunque recientemente algunas embarcaciones han sido dotadas de compartimientos aislados donde se almacena el pescado con hielo.

Estas embarcaciones no son adecuadas para efectuar un trabajo eficiente de selección y limpieza del pescado, por cuanto su tamaño resulta reducido en relación al volumen de las capturas que no dejan área libre para realizar tales labores. Se trata en realidad, de barcos de tipo purse-seiner construidos originalmente para la pesca de anchoveta o bonito y que han sido adaptados para la pesca de arrastre, mediante la instalación de una maquinilla *ad hoc* y arcos en la popa. Estas embarcaciones son todas de madera y tienen una eslora promedio de 17 m (56 ft), con motores de potencia no mayor a los 220 hp, que limitan la profundidad de pesca a un máximo de 140 m (460 ft). Sin embargo, la mayor parte de la captura la realizan entre los 50 y 100 m (164 y 328 ft) de profundidad. Todo el pescado es desembarcado entero y en algunos casos cuando la cantidad capturada es muy grande, la selección de las distintas especies sólo puede hacerse en el momento de la descarga.

El pescado utilizado en la planta de fileteo es adquirido de una flota de 30 embarcaciones que trabajan en la zona indicada. La venta del pescado se lleva a cabo bajo la forma de mercado libre sujeto a la oferta y la demanda. Parte del pescado es adquirido por comerciantes que lo transportan a los mercados en camiones isotérmicos enfriados con hielo triturado. El pescado es colocado dentro de estas cámaras, acomodado en capas separadas con pisos de madera.

El pescado obtenido para la planta de fileteo es previamente lavado con agua de mar y conservado en hielo dentro de una cámara fría hasta el momento del procesado.

Toda la operación de fileteo se realiza a mano, los filetes son colocados en moldes de acero inoxidable para obtener porciones de 0,5 kg para consumo familiar, que miden 22 cm (8,6 in) de largo, 8 cm (3,2 in) de ancho y 2,5 cm (1 in) de espesor. También se producen porciones de 5 kg (11 lb) para el consumo institucional, porciones que miden 44,5 cm (17,5 in) de largo, 34,5 cm (13,5 in) de ancho y 2,5 cm (1 in) de espesor. Las porciones son congeladas en la máquina de placas horizontales antes citada.

El tiempo promedio de congelación varía en algunas especies, habiéndose observado que el toyo requiere un tiempo mayor de congelación, en relación a otras especies; requiriendo 80 min a −30°C (−22°F) para obtenerse una buena congelación, mientras que las otras especies trabajadas en esta planta requieren un promedio de 60 min a la misma temperatura.

Los rendimientos de filete por especie presentan grandes variaciones y son anotados en el Cuadro 1, que resume el resultado promedio durante el año 1966:

CUADRO 1. RENDIMIENTO PROMEDIO DE FILETE EN RELACION A PESCADO ENTERO

Especie	*Con piel* (%)	*Sin piel* (%)
Lenguado (*Paralichthys adspersus*)	49,0	35,6
Toyo (*Mustelus* sp.)	—	21,1
Coco (*Paranlonchurus peruanus*)	25,0	21,6
Merluza (*Merluccius gayi peruanus*)	34,3	29,0
Cachema (*Cynoscion analis*)	36,9	—
Congrio (*Genypterus maculatus*)	—	21,0

Las porciones son envasadas en bolsas de polietileno impresas y luego en cajas de cartón ondulado que contienen 40 porciones de 0,5 kg (1,1 lb) o 5 porciones de 5 kg (11 lb) y en esta forma se transportan a los mercados. Hasta el momento de ser transportadas, las cajas se almacenan a −20°C (−4°F).

PROBLEMAS DE DISTRIBUCION Y COMERCIO DE FILETES CONGELADOS

El principal mercado para filetes congelados en el Peru es la capital, Lima, situada a 1,250 km (750 mi) al sur de Paita.

Por razones de economía el transporte puede realizarse solamente por carretera, habiéndose ensayado utilizar camiones con sistemas de refrigeración propia. Se encontró, sin embargo, el inconveniente de que las vibraciones producidas por el mal estado de algunos trechos de la carretera, ocasionan con frecuencia la rotura de las tuberías del sistema refrigerante. Además, la arena del desierto que debe atravesarse en casi toda la ruta obstruye los condensadores. Estos problemas obligan a que los productos congelados sean transportados en cámaras sin refrigeración propia, o sea, en cámaras isotérmicas construidas sobre los camiones y aisladas con planchas de 10 cm (4 in) de polietileno expandido.

El transporte de los filetes congelados se hace con la ayuda de hielo seco, el cual se coloca dentro de las cámaras isotérmicas junto con las cajas de filetes. La proporción aproximada que se utiliza es de 5 kg por m^3 (0,3 lb/ft^3) de cámara. Es interesante notar que el promedio de capacidad de las cámaras es de 15 m^3 (530 ft^3) en las que se transportan 6 t de filetes. Con este sistema que la empresa considera práctico, pero lejos de ser perfecto, se ha logrado subsanar momentáneamente el problema del transporte de los filetes congelados. El viaje entre Paita y Lima normalmente dura 20 horas a través de territorios desérticos que suelen alcanzar

durante el día, temperaturas hasta de 34°C (93°F) a la sombra. Al llegar a Lima los filetes son descargados directamente a una cámara conservadora que se mantiene a −20°C (−4°F), desde la cual son distribuidos hasta los puntos de venta. La venta de los filetes congelados es en el Perú la etapa más difícil de esta industria. Existe resistencia entre el público hacia el consumo de pescado, que se acentúa aún más al tratarse de productos congelados. Además, la falta de una gran cadena de establecimientos con instalaciones para la conservación de productos congelados, dificulta enormemente su distribución y en este caso particular, el productor ha debido adquirir sus propios equipos de exhibición y venta para favorecer la salida de sus productos.

En las ventas, un 55 por ciento de los filetes fueron colocados directamente al público por medio de supermercados y otras tiendas y 45 por ciento fueron consumidos por instituciones.

CONCLUSION

La empresa considera que la venta de 200 t de filetes congelados en su primer año de introducción es en todo caso un buen comienzo, tratándose de un producto totalmente nuevo en el mercado y desconocido por la gran mayoría de los consumidores. Cree asimismo que el consumo potencial es amplio por lo que mira con bastante optimismo el futuro en este campo.

Le développement de la congélation en mer et à terre et de la consommation du poisson congelé dans les pays tropicaux de l'ouest africain

par R. A. Moal et J. Gousset

Le développement de la congélation en mer et à terre et de la consommation du poisson congelé dans les pays tropicaux de l'Ouest africain

L'exploitation industrielle systématique des eaux de l'Atlantique tropical n'a pris un réel essor que depuis 10 ans environ, permettant de porter le volume des captures tirées de ces eaux de 200 000 t environ à 750 000 t en 1966.

Ce remarquable progrès est dû essentiellement soit directement, soit indirectement à l'effort de pays industrialisés non africains.

Mais de récentes études ont montré que compte tenu de l'évolution démographique et de celle du niveau de vie, la consommation globale de poissons en 1970 dans les 14 pays de l'Afrique de l'Ouest devrait être de 998 000 t dont 772 000 t environ de poisson de mer.

Etant donné les exportations vers le reste du monde par les pays africains excédentaires, en fait, le déficit global de l'Afrique de l'Ouest pour sa consommation serait de 304 000 t contre 250 000 t en 1964.

L'accroissement des besoins devrait se traduire par une augmentation de 54 000 t des importations en provenance du reste du monde, car les Etats africains excédentaires sont à même de fournir 40 000 t environ dont 18 000 t de poisson congelé pour la satisfaction partielle des besoins des Etats déficitaires qui devraient importer 94 000 t de plus qu'en 1964.

Si, pour tenir compte de la conjoncture on admet que l'accroissement de la consommation de poisson congelé se maintiendra au moins à son niveau actuel, on peut espérer qu'elle représentera environ 100 000 t en 1970 contre 55 000 t en 1964.

L'engouement des populations pour le poisson congelé s'explique car il représente plus un aliment qu'un condiment, rôle traditionnellement dévolu au poisson transformé qui seul précédemment pouvait atteindre le consommateur éloigné des points de débarquement de la pêche.

Cependant un certain nombre de conditions sont impératives pour assurer le développement de la consommation du poisson congelé et essentiellement celles ayant trait:

1°/—à la qualité du produit
2°/—à son prix.

Dans une telle optique, il sera recherché la congélation à bord en saumure pour toutes les espèces industrielles susceptibles d'être transformées avant consommation, dans les autres cas la congélation devrait s'orienter vers la congélation à plaques verticales ou horizontales, fonction du type de produit à traiter.

Les installations pour les produits congelés au port de débarquement devraient être surtout des entrepôts de stockage car il est important que les secteurs pêche fraîche et pêche congelée soient nettement séparés, le volume des produits traités, leur nature et leur destination étant beaucoup trop différents pour que les deux circuits soient confondus.

L'état des voies de communication et la dispersion des points de vente de détail ne permettent pas d'envisager dès à présent l'utilisation de camions ayant leur propre source de froid pour la distribution des produits congelés des entrepôts portuaires ou relais aux détaillants.

De telles dispositions, en contradiction avec les principes fondamentaux d'utilisation du froid, ne peuvent être retenues que parce qu'elles tiennent compte du caractère propre du consommateur africain qui n'achète du poisson qu'en vue de sa consommation immédiate.

Leur application a été le principal artisan du développement de la consommation du poisson de mer dans les pays de l'Afrique de l'Ouest dont seulement quatre d'entre eux peuvent assurer actuellement une couverture correcte des besoins physiologiques théoriques minimum en protéines d'origine animale de leur population.

Development of freezing at sea and ashore and of the consumption of frozen fish in tropical West Africa

The systematic working of the fishing grounds of the Atlantic off tropical Africa has gained momentum only in recent years, chiefly following the arrival of the Russian, Japanese, Spanish and French freezer-trawler and tuna boat fleets. The remarkable progress achieved is due, both directly and indirectly, to the efforts of non-African industrialized countries.

Recent surveys have shown that, with the population increase and rise in living standards, the overall consumption of fish by 1970 in the 14 countries of West Africa should be 998,000 t, of which some 772,000 t would be supplied by sea fish. Accordingly, taking into account the exports to the rest of the world by African countries having a surplus, there would in fact be an overall deficit for the 14 countries in question of the order of 304,000 t, as compared with 250,000 t in 1964.

Expansion in demand should result in a 54,000 t increase in imports from the rest of the world, since the African countries that have a surplus are in a position to supply some 40,000 t (18,000 t of this being frozen fish) to meet a proportion of the demand of the fish-deficit countries, which had to import 94,000 t in 1964.

Assuming that the present rate of increase in the consumption of frozen fish will be maintained, one may expect that figures will rise from the 1964 level of 55,000 t to approximately 100,000 t in 1970.

The enthusiasm evinced for frozen fish is to be explained by the fact that it is more of a food than a condiment, a role which in the past belonged to fish processed in some way or other, since this was the only form in which it could be got to the consumer living at great distances from the ports of landing.

Nevertheless, certain aspects of the problem must be satisfactorily dealt with if the consumption of frozen fish is to expand, chief among them being (1) quality and (2) price.

Efforts will be directed to encouraging shipboard freezing, in brine, of all species suitable for processing, while, with other fish, depending on the species, preference should go to the use of vertical or horizontal plate freezers.

Installations for frozen fish at the ports of landing should consist for the most part of storage facilities. It is essential, moreover, that the areas for fresh fish and frozen fish be kept quite separate, since the volumes handled and the nature and destination of the products are too unlike each other for any confusion between them to be tolerated.

The state of the roads and the dispersion of the retail outlets at the present time preclude the use of refrigerated trucks for the distribution of the frozen products from the port or from up-country cold depots to retailers, since arrangements of the kind go counter to the fundamental principles of refrigeration merchandising and can only be considered to the extent that they make allowance for the ways of the African consumer, who only buys fish when he intends to eat it immediately.

The adoption of the correct approach has been the chief contributory factor in the expansion in the consumption of sea fish in West Africa, where still only four of the countries in this region are able to supply the theoretical minimum physiological needs of their populations where animal protein is concerned.

Desarrollo de la congelación a bordo y en tierra y del consumo de pescado congelado en los países tropicales del Africa occidental

La explotación industrial sistemática de las aguas del Atlántico tropical comenzó realmente hace unos diez años, lográndose que el volumen de las capturas obtenidas en estas aguas pasara de 200 000 t aproximadamente a 750 000 en 1966.

Este extraordinario progreso se debe, en lo esencial, ya sea directa o indirectamente, al esfuerzo de países industrializados no africanos.

No obstante, estudios recientes han demostrado que teniendo en cuenta la evolución demográfica y la del nivel de vida, el consumo total de pescado en 1970 en los 14 países del Africa occidental, será de 998 000 t, de las cuales 772 000, aproximadamente, de pescado de mar.

Teniendo en cuenta las exportaciones al resto del mundo por parte de los países africanos excedentarios, de hecho, el déficit global del Africa occidental para su consumo será 304 000 t, frente a 250 000 en 1964.

El incremento de las necesidades debe traducirse en un aumento de 54 000 t de las importaciones procedentes del resto del mundo, ya que los Estados africanos excedentarios facilitarán 40 000 t, de las cuales unas 18 000 serán de pescado congelado que se destinarán a la satisfacción parcial de las necesidades de los Estados deficitarios que deben importar 94 000 t más que en 1964.

Si, con objeto de tener en cuenta la coyuntura, se admite que el aumento del consumo de pescado congelado se mantendrá, por lo menos, a su nivel actual, puede esperarse que tal aumento representará alrededor de 100 000 t en 1970, frente a 55 000 en 1964.

La preferencia de las poblaciones por el pescado congelado se explica porque constituye más un alimento que un condimento, papel tradicionalmente reservado al pescado elaborado que era el único que precedentemente podía llegar al consumidor que vivía lejos de los lugares de desembarque del pescado.

Sin embargo, hay varias condiciones absolutamente necesarias para asegurar el desarrollo del consumo de pescado congelado, esencialmente las que se refieren a:

1°—la calidad del producto
2°—su precio.

Teniendo esto en cuenta, convendrá realizar a bordo la congelación en salmuera de todas las especies industriales susceptibles de elaborarse antes del consumo, y en los otros casos la congelación deberá orientarse hacia el método en placas verticales u horizontales, en función del tipo de producto que hay que tratar.

Las instalaciones destinadas a los productos congelados en el puerto de desembarque deben consistir, sobre todo, en almacenes, pues conviene que los sectores destinados al pescado fresco y al congelado se hallen netamente separados, siendo muy diferentes el volumen de los productos tratados, su naturaleza y su destino para que puedan confundirse los dos circuitos.

El estado de las vías de comunicación y la dispersión de las pescaderías no consienten prever en la actualidad la utilización de camiones frigoríficos para la distribución de los productos congelados desde los almacenes portuarios a las pescaderías.

Tales disposiciones, en contradicción con los principios fundamentales de la utilización del frío, sólo pueden mantenerse porque tienen en cuenta el carácter peculiar del consumidor africano, que sólo compra pescado cuando quiere consumirlo inmediatamente.

A su aplicación se debe el desarrollo del consumo de pescado marino en los países del Africa occidental, de los cuales solamente cuatro pueden garantizar en la actualidad que a sus poblaciones se les suministran los alimentos precisos para cubrir las necesidades fisiológicas teóricas mínimas en proteínas de origen animal.

L'EXPLOITATION industrielle systématique des eaux de l'Atlantique tropical africain n'a pris un réel essor que ces dernières années, essentiellement depuis l'arrivée des flottilles de chalutiers et thoniers congélateurs russes, japonais, espagnols et français.

C'est ainsi que les captures de poisson de fond sur et aux accores des plateaux continentaux de l'Atlantique africain situés entre les tropiques, ont atteint en 1966 environ 400 000 t et que celles des poissons de surface côtiers ou océaniques dans cette même zone se sont élevées à 350 000 t environ, alors que le total ne dépassait guère 200 000 t environ il y a 10 ans.

Ce remarquable progrès est dû essentiellement, soit directement, soit indirectement, à l'effort de pays industrialisés non africains qui, pour satisfaire leurs besoins propres en accroissement constant, n'ont pas hésité à investir dans des unités importantes destinées à exploiter de nouveaux fonds de pêche encore peu ou pas fréquentés mais fort éloignés de leur côte.

Dans ce cas, quels que soient le ou les types de techniques de capture retenues, toutes les unités se devaient de posséder des sources de froid importantes destinées à stabiliser les produits pêchés, par la congélation, en attendant leur conditionnement soit à bord, soit à terre, ultérieurement à l'issue de la compagne.

Bien que les captures de ces unités soient essentiellement destinées aux consommateurs des pays d'origine des navires, il est apparu soit parce que ces marchés étaient sélectifs eu égard à un certain nombre d'espèces, soit parce que l'on pouvait allonger et donc accroître la rentabilité des campagnes si on les interrompait momentanément par des escales avec livraison d'une partie des captures dans un pays côtier africain, qu'il pouvait être intéressant pour ces flotilles de vendre aux pays côtiers africains une partie de leur pêche.

En 1966, on peut estimer à environ 70 000 t les quantités de poisson congelé ainsi débarquées. La qualité des produits, la facilité de leur manutention, la diminution sensible des pertes par rapport aux poissons glacés lors de la distribution, leur aptitude au traitement traditionnel ultérieur par le fumage sont autant de facteurs qui expliquent contre toute attente le succès du poisson congelé auprès du consommateur africain.

Il faut remarquer que ce succès totalement imprévisible du fait du manque de chaîne de froid pour assurer une distribution satisfaisante des produits congelés, est cependant logique car il est fondé sur trois caractéristiques propres à la distribution du poisson et au consommateur en Afrique:

(1) Lorsque celui-ci peut trouver du poisson frais de qualité, il le préfère à toute autre forme de présentation: salé, séché, fermenté, fumé, etc.

(2) Seul le poisson congelé peut supporter les conditions particulièrement dures du transport routier en zone tropicale ou équatoriale, le poisson à la glace étant au contraire, même dans de bonnes conditions de température, trop traumatisé pour attirer le consommateur.

(3) Le volant de froid que représente une masse de poisson congelé protégé par un écran de quelques centimètres de sciure dans des sacs, placé dans une camionnette convenablement bâchée, est suffisant, en l'absence de toute chaîne de froid, pour assurer une température négative de l'ensemble pendant plusieurs heures, permettant d'atteindre des marchés parfois situés à plus de 200 km de la côte où les acheteurs, dès la transaction faite, sans solution de continuité, procèdent à la cuisson du poisson acheté pour la consommation dans les heures qui suivent; la confection des plats traditionnels demandant une cuisson relativement longue.

C'est ainsi que rapidement le poisson congelé a suscité un tel engouement que la congélation a été systématiquement envisagée par les autorités responsables du

développement des pêches maritimes dans les pays africains, lors de la préparation de leurs plans d'équipement.

En effet, devant la nécessité, non seulement d'apporter à une population déjà sous-approvisionnée en protéines animales, un complément destiné à lui permettre de satisfaire ses besoins minimum, mais aussi de faire face à un accroissement explosif de ces besoins du fait d'une démographie en rapide expansion, seul le recours à l'exploitation des ressources marines peut permettre d'espérer pallier le déficit des sources terrestres de ces protéines.

On estime, d'après les chiffres d'une étude récente (Salmon et Lagoin, 1967) que pour atteindre des objectifs, il faudrait disposer en 1970 d'un complément de 210 000 t de poissons et crustacés par rapport aux débarquements de 1964 pour l'ensemble des 14 pays de l'Afrique de l'ouest.

Il est bien évident qu'un tel volume de captures ne peut être obtenu par les pêcheurs de ces pays sans le recours à des techniques à haute productivité dont la mise en oeuvre est susceptible d'assurer des rendements comparables à ceux d'armements modernes de pays industrialisés. De plus, soit parce que la nature d'une partie des captures attendues est mal connue du futur consommateur africain (soles) ou peu prisée par lui (thonidés), soit parce que le marché mondial largement ouvert à certains produits (crevettes et langoustes) offre des prix d'autant plus intéressants que leur exportation est une source de devises particulièrement nécessaire au développement de l'économie de ces pays, une partie de la production sera destinée aux marchés des pays industrialisés extra-africains.

Pour avoir une chance de prendre une place sur ces marchés, les produits d'origine africaine devront être concurrentiels, tant par la qualité que par les prix, avec ceux livrés par les propres flottes des pays importateurs.

On peut conclure que la pêche dans l'Atlantique tropical, qu'elle soit pratiquée par des unités appartenant à des flottilles de pays industrialisés ou à celles de pays en voie de développement, sera désormais destinée à deux types de marché qui se définissent ainsi:

(1) Les espèces à forte demande internationale (poissons fins et crustacés) seront en majeure partie dirigées vers les pays fortement industrialisés à haut pouvoir d'achat, valorisant au mieux l'effort de pêche.

(2) Les espèces communes, soit à gros rendement (sardinelles par exemple), soit d'une qualité qui ne leur permet pas de concurrencer les poissons traditionnels des mers tempérées ou froides (certains *Sciennidés, Polynémidés, Carangidés, Epiphiidés*, etc.), trouveront un débouché sur place, soit directement dans les pays à façade maritime, soit mieux dans les pays de l'intérieur.

L'existence de ces deux marchés implique, pour être assuré d'une souplesse indispensable à des transactions aussi variées, le recours à la congélation, car seule cette dernière est susceptible de stabiliser les produits de la mer dans l'état le plus voisin possible de celui qu'ils ont à la sortie de leur élément naturel et nous avons vu que ceci est un facteur déterminant pour le consommateur, que ce soit pour la consommation en l'état ou pour un traitement ultérieur préalable à celle-ci.

La congélation, particulièrement en climat chaud, est un procédé relativement coûteux. Si les produits destinés aux consommateurs de pays industrialisés peuvent aisément en supporter le prix qui ne représente généralement, stockage compris, qu'au maximum 10 pour cent du prix f.o.b., il reste que les poissons africains ont cependant à subir la concurrence des produits fournis par d'autres fournisseurs le plus souvent susceptibles de faire une politique commerciale de compensation sur leur propre marché.

Mais l'incidence du prix de la congélation sur le prix des poissons présentés à l'acheteur revêt un intérêt capital lorsqu'on s'adresse au marché des pays en voie de développement, dans lesquels le pouvoir d'achat de la masse des consommateurs qui a précisément le plus besoin de poissons, est particulièrement bas.

Dans une telle conjoncture les problèmes particuliers de l'application de la congélation en mer et à terre aux produits de la pêche destinés à la consommation des pays en voie de développement, méritent un examen plus approfondi.

LA CONGELATION DANS LES PAYS DE L'OUEST AFRICAIN

Congélation en mer

Poissons de fond. Bien qu'ils aient été de tous temps recherchés par les consommateurs africains car, traditionnellement capturés à la ligne à main, ils ne touchaient il y a encore quelques années, du fait de leur prix, qu'une clientèle ayant déjà certains disponibilités monétaires.

L'apparition du chalutage a sensiblement modifié ce schéma en apportant sur le marché de nombreuses espèces de fond généralement pas connues des pêcheurs traditionnels, de valeur gustative médiocre, mais en quantités suffisantes pour supporter un prix de vente assurant une plus grande diffusion que les espèces précédemment envisagées.

Lorsque la proximité des lieux de pêche le permet, il ne saurait être question de recourir à bord des chalutiers à d'autres moyens de conservation que la réfrigération, d'autant que les espèces capturées en eaux chaudes se conservent généralement beaucoup mieux (exception *Merlucius senegalensis* par exemple) à des températures voisines de 0°C que celles capturées dans les eaux tempérées ou froides. Pour les espèces des mers tropicales l'abaissement de température bloque mieux les processus biochimiques *post mortem* du fait du plus grand écart de température entre celle de l'animal vivant et celle de sa conservation après sa pêche que pour celles tirées des mers tempérées ou froides.

Il est cependant bon de rappeler que la plus grande partie des fonds de pêche de l'Afrique tropicale, hormis ceux qui sont périodiquement enrichis par des mouvements de masse d'eau particuliers, ont une productivité beaucoup plus basse que ceux des mers tempérées. De plus ils ont une superficie relativement faible par rapport aux fonds de pêche de l'Atlantique tempéré ou froid (du Rio del Oro au sud-ouest africain 400 000 km² contre 2 500 000 km² pour l'Atlantique européen et 2 400 000 km² pour l'Atlantique américain). Enfin, les associations animales qui s'y rencontrent sont caractérisées par une très grande variété d'espèces représentées

proportionnellement aux mers froides par un beaucoup plus faible nombre d'individus.

Il apparaît ainsi que les chalutiers sont de plus en plus appelés à accroître les distances à parcourir et à allonger la durée de leur marée et que la congélation à bord devra de plus en plus intervenir chaque fois que des unités pêcheront sur les lieux de pêche éloignés de plus de cinq jours de route du port ou qu'elles destineront une partie de leurs captures à l'exportation.

Dans le premier cas, il s'agit d'unités de fort tonnage destinées à fréquenter les zones subtropicales, soit du Rio del Oro/Mauritanie, soit de l'Angola Sud-Ouest Africain/Afrique du Sud. Les problèmes posés sont identiques à ceux recontrés par les chalutiers classiques européens fréquentant les mêmes lieux en ayant cependant présent à l'esprit que les coûts de production devront être plus bas étant donné la différence de marché.

Dès la capture, après un tri préalable par grands groupes de tailles et d'espèces, les poissons seront placés en milieu réfrigéré (durée maximum trois jours) pour éviter l'apparition trop rapide de la rigidité qui, si cela était, entraînerait une séparation des blocs musculaires lors de la congélation et rendrait le poisson invendable après la décongélation.

Les poissons seront congelés entiers, simplement éviscérés, soit à l'air, soit mieux en congélateurs à plaques verticales.

Ils seront ensuite conditionnés en cartons et stockés prêts à leur distribution de détail.

Dans le deuxième cas, le tri à bord des espèces en deux catégories, celles destinées au marché local et celles destinées au marché d'exportation, sera obligatoire.

Les installations de congélation à bord devront être alors suffisamment souples pour pouvoir traiter des poissons ou des parties de poissons dont la forme et la taille peuvent varier dans de notables proportions.

Seule, dans les conditions présentes du marché, l'exploitation des espèces de fond, conçue dans cette dernière optique, est susceptible d'être économiquement rentable pour des armements constitués par des chalutiers congélateurs basés dans un pays africain de l'Atlantique tropical.

Produisant pour deux marchés distincts, dont l'un à fort pouvoir d'achat mais exigeant sur la nature des espèces présentées, l'autre au contraire plus ouvert mais disposant de peu de facilités de paiement, un tel chalutier appelé à fréquenter les eaux subtropicales, sera plus aisé à rentabiliser que s'il est basé dans un pays européen.

Ceci suppose bien entendu qu'il dispose:

d'une main d'oeuvre locale apte à ce mode de vie;

que le pourcentage des espèces destinées au marché des pays développés soit suffisant;

qu'enfin, dans son port de base, il soit assuré de trouver un minimum d'infrastructures portuaires essentiellement pour le débarquement des produits destinés au marché local et pour leur stockage éventuel.

Sur ce dernier point, l'avantage du chalutier congélateur sur tout autre navire est indiscutable, car sa taille, sa puissance et ses capacités de stockage le rendent apte à livrer directement ses produits destinés au marché des pays industrialisés, sans rupture de charge, ayant laissé en cours de campagne la plus grande partie du poisson destinée aux marchés africains dans un port de cette région.

Il en résulte, pour les pays en voie de développement, généralement encore sous-équipés, un avantage certain car la mise en activité de telles unités nécessite des infrastructures et superstructures d'accueil légères de simple stockage adaptées au seul besoin du marché local, donc réalisables rapidement.

Avant d'examiner la situation pour les espèces de surface, il est nécessaire de mentionner le problème des crustacés, essentiellement dans la zone considérée: les crevettes. Le développement spectaculaire de leur pêche a été possible grâce à la venue d'unités techniquement dépassées dans leurs pays d'origine, conservant leurs captures à la glace après cuisson à bord pour les congeler à terre, car elles étaient destinées essentiellement au marché français.

Dans la mesure où les produits seraient destinés à d'autres marchés, en particulier les Etats-Unis d'Amérique où la présentation, essentiellement en queues, doit être particulièrement soignée, il faudra là aussi s'orienter vers le conditionnement et la congélation en mer, à la suite d'un pré-stockage en eau de mer refroidie; les crevettes seront travaillées, conditionnées et congelées dans des congélateurs à plaques et stockées en cale à −18°à−20°C (0°à−4°F), la congélation en saumure ne semble envisageable que pour les crustacés de petites tailles destinés à un traitement ultérieur avant consommation, tel que l'appertisation par exemple.

Poisson de surface. Il est nécessaire de distinguer les poissons de surface côtiers et océaniques.

Les poissons de surface côtiers représentent la véritable richesse des eaux tropicales, particulièrement dans les zones où les phénomènes hydrologiques saisonniers assurent un enrichissement régulier de ces eaux en sels nutritifs. Là l'extraordinaire explosion de la vie dans les eaux de surface grâce à la photo-synthèse entraîne des concentrations importantes de ces poissons près des côtes.

Dans la mesure où ils sont destinés aux marchés situés près des points de débarquement, la durée des marées des navires destinés à leur capture ne devrait pas dépasser quatre à cinq jours. Dans ce cas, les unités (18 à 25 m h.t.) qui pratiquent actuellement la pêche de ce poisson s'avèrent convenablement adaptées, à la condition toutefois d'être équipées de cuves en eau de mer refroidie par un procédé mécanique et non par de la glace ajoutée à cette eau de mer comme c'est le cas la plupart du temps.

En effet, si l'utilisation de la glace directement en l'état, doit être bannie par suite, d'une part de son coût élevé (environ 30 pour cent du prix du poisson à la vente au quai), d'autre part de la très faible durée de conservation qu'elle procure, il en est de même du procédé adopté de refroidissement de l'eau de mer par addition de glace. Cette technique ne permet guère de descendre la température du poisson à coeur plus bas que 10°C (50°F), la durée de son utilisation est donc limitée à quelques heures.

Dans le cas où les apports de ces unités réfrigérées devraient être stockés soit par suite de leur abondance en fonction des possibilités du marché, soit en vue de leur

distribution près des consommateurs situés assez loin des points de débarquement, le fumage reste la solution la plus économique.

Cependant, comme nous l'avons déjà mentionné chaque fois que le consommateur voit son pouvoir d'achat s'accroître, il recherche de préférence le poisson frais à tout autre conditionnement.

Les moyens de communication ne permettent que rarement le transport sous glace dans des conditions satisfaisantes. Le recours à la congélation à terre s'avère alors indispensable. Il semble dans ce cas que les servitudes de la congélation à bord n'existant plus, la congélation par congélateur à plaques verticales, bien que légèrement d'un moins bon rendement que la congélation en saumure, soit la solution à retenir, du moins si les tonnages à traiter présentent une certaine irrégularité et une valeur d'environ 50 t maximum pour 24 h. Dans les autres cas, le recours à la congélation en saumure s'avère nécessaire avec conditionnement préalable selon des dispositions identiques à celles décrites ci-après:

Les poissons de surface côtiers sont traditionnellement consommés dans tous les pays de l'Afrique de l'ouest et la demande de ceux-ci, dans les conditions actuelles de distribution, soit le plus souvent fumés avant consommation, est en croissance continue. Compte tenu de la situation économique de ces pays, on peut estimer à 25 000 t le déficit actuel entre l'offre et la demande. Il existe donc un marché potentiel. Compte tenu des conditions hydrologiques rencontrées le long de cette côte de l'Afrique intertropicale, il ne pourra être satisfait qu'à partir de l'exploitation de deux ou trois zones de pêche situées parfois à plusieurs jours de mer des ports de débarquement.

Le recours à la congélation à bord des navires paraît s'imposer dans ce cas pour combler le déficit actuel et futur dans l'approvisionnement en poissons de surface côtiers des pays de l'Afrique de l'Ouest intertropicale, ce que ne pourront faire les flottilles traditionnelles et modernes du fait de l'insuffisance de leur équipement. Etant donné:

la faible valeur marchande du produit au débarquement au port dans ces pays (prix moyen 35/38 F CFA) et la nécessité de maintenir son prix de vente au détail suffisamment bas pour en assurer la plus grande diffusion en milieu économiquement faible;

la productivité élevée de la technique de la pêche au filet tournant;

le traitement préalable par fumage très souvent pratiqué avant consommation, dont le rôle dans l'avenir diminuera indiscutablement mais qui reste le seul moyen peu onéreux de conservation temporaire pour le consommateur africain dans sa structure familiale.

La congélation en saumure à bord, poisson conditionné en caisses de 25 kg type *Mussy codica* en bois déroulé à claire-voie, apporte une solution satisfaisante car elle permet de maintenir le poisson dans sa forme initiale au moment de l'action du froid, ce qui n'est pas le cas pour le poisson congelé en vrac et elle limite au maximum au déchargement au port les difficultés de manutention et de conditionnement à terre qui ne manquent pas d'apparaître dans le cas du recours à la congélation à terre pour un produit déjà plus fragile qu'au sortir de l'eau, puisque conservé actuellement plusieurs heures à des températures franchement positives. Ces difficultés se maintiendraient dans l'avenir même si l'utilisation de l'eau de mer réfrigérée mécaniquement se généralisait à bord car le poisson serait malgré tout maintenu à des températures voisines de 0°C pendant quelques jours avant la congélation.

Les travaux de Aldrin (1966) ont montré que la congélation en saumure pour les sardinelles:

(1) augmentait le taux des chlorures d'environ 2,5 fois mais que le taux de sel ne dépassait pas 0,68 pour cent du poids du poisson, ce qui est inférieur au résultat du salage habituel pour la cuisson;
(2) que l'aptitude au fumage est intégralement conservée à condition que le poisson soit frais avant congélation, cette opération entraîne même une diminution du taux des chlorures dans le produit fini par rapport au poisson avant fumage;
(3) que des résultats satisfaisants ne peuvent être obtenus que si le poisson est convenablement glacé après congélation par trempage dans l'eau douce;
(4) que le poisson, soigneusement traité, peut supporter un stockage de deux mois sans modification de ses qualités premières;
(5) que si le poisson n'est pas très frais avant congélation, les résultats deviennent très mauvais car le salage est plus intense et, au fumage, le poisson prend mal la fumée, il tombe souvent dans le foyer par relâchement des tissus avant coagulation des protides.

La congélation à bord donne la possibilité aux navires de pêche qui en disposent, à condition que leurs cales aient une capacité de stockage des produits congelés d'au moins 300 t, de livrer leur pêche directement des lieux de pêche aux ports des pays importateurs, sans rupture de charge et dans des conditions de transport économiquement intéressantes.

Le cas des poissons de surface océaniques tels que les thonidés est sensiblement différent. Pêchant à l'appât vivant ou à la senne depuis de nombreuses années, les thoniers modernes qui fréquentent régulièrement l'Atlantique tropical, ont tous recours à la congélation en saumure car ces navires sont tenus de rester à la mer en permanence pendant un à deux mois pour la recherche et la capture des bancs de thon. Ils doivent être à même de traiter des poissons de taille variable avec une grande et brutale variation du volume des apports. Par contre, les thoniers pratiquant la technique de la longue ligne, pour lesquels les apports journaliers sont très réguliers et d'un volume plus faible ne peuvent tirer parti de la congélation en saumure.

D'une part la nécessité devant laquelle ils se trouveraient de congeler en plusieurs fois le contenu d'une cuve, du fait d'une production journalière de quelques tonnes au maximum, au fur et à mesure des apports successifs, avant de passer à la suivante, entraînerait le pré-stockage en eau de mer réfrigérée avant congélation qui poserait des problèmes d'arrimage du poisson dans la cuve (chocs contre parois) et imposerait une durée trop longue pour que la congélation ultérieure donne un produit satisfaisant.

D'autre part, les thons capturés sont souvent de très grande taille. Ils doivent être débités avant congélation et ceci interdit le recours à la saumure sous peine d'altération superficielle des chairs et d'une pénétration importante irréversible de sel dans les tissus des poissons.

En outre, les volumes disponibles seraient plus faibles, d'accès moins aisé et les cuves seraient pratiquement inutilisables pour d'autre stockage que le poisson.

Enfin, le stockage de l'appât mort congelé en cuve, poserait des problèmes très difficiles pour son emploi puisqu'il faudrait chaque fois décongeler la totalité de la cuve avant de pouvoir disposer d'une faible partie pour l'emploi immédiat.

Il faut aussi noter que la presque totalité des thoniers congélateurs actuels travaillant à l'appât vivant ou à la senne, ont des capacités frigorifiques nettement inférieures aux besoins, ce qui conduit à une congélation lente dans la plupart des cas.

Il m'a été donné de constater que les températures du poisson à coeur durant le stockage étaient souvent égales ou supérieures à −11°C (16°F), ce qui est nettement insuffisant.

Dans le cas des thoniers pêchant à l'appât vivant particulièrement, l'irrégularité des apports entraîne, soit des durées trop importantes d'entreposage en eau de mer ou en saumure à des températures positives, soit des stockages de quantités insuffisantes de thons congelés dans la saumure par rapport au volume de la cuve, provoquant des chocs et écrasement des chairs nuisibles à une bonne présentation du produit à l'issue du traitement ultérieur en conserves appertisées par exemple, soit une congélation lente avec forte pénétration de sel dans les chairs qui conduit à donner au poisson, lors d'un stockage à sec à l'entrepôt frigorifique ou dans les cales d'un cargo congélateur transporteur, un aspect suintant, la chair ne présentant plus la rigidité souhaitable, avec toutes les conséquences biochimiques et organoleptiques que l'on peut en attendre. Pour éviter toute altération irrémédiable et les refus de poisson par les autorités chargées du contrôle sanitaire au port de débarquement, refus qui ne feront qu'augmenter avec la recherche d'un contrôle plus rigoureux indispensable si l'on veut atteindre les marchés d'exportation, les températures de stockage à bord devraient être garanties à un niveau inférieur à −18°C bien que cela conduise à un supplément de dépenses d'équipement et une augmentation du coût du stockage.

Il apparaît donc important que dans la construction des futurs thoniers congélateurs senneurs,à appâts vivants ou mixtes, les puissances frigorifiques nécessaires soient étudiées avec soin pour que l'on puisse assister à une amélioration sensible de la qualité des thons débarqués qui actuellement, il faut bien le dire, laisse parfois à désirer.

Congélation à terre

La congélation à terre ne semble pas présenter le même intérêt que la congélation à la mer pour les pays en voie de développement de l'Afrique atlantique. En effet, elle ne peut jouer un rôle que dans la mesure où:

(1) la pêche est le fait d'unités d'un certain âge, reconverties à partir d'armements périmés dans leur pays d'origine en Europe et qui, de ce fait, ont des moyens insuffisants pour assurer une bonne conservation des poissons à bord, au delà de la durée limitée de leurs marées;
(2) les produits de cette pêche étant destinés au marché local et celle-ci étant irrégulière avec des surplus de production imprévisibles, il n'existe pas d'autres moyens de conservation en place, satisfaisants sur le plan de la qualité et des prix;
(3) certains des produits de cette pêche étant destinés à l'exportation, il est évidemment nécessaire de les conditionner et de les stabiliser afin de leur assurer une qualité irréprochable, seule possibilité de leur garantir, face à la concurrence, une place sur les divers marchés étrangers.

Dans tous les cas, l'importance des installations devra être étudiée avec soin sous peine de les voir rapidement disproportionnées aux besoins.

Il devra être tenu le plus grand compte du fait que les circuits traditionnels, à partir de poissons séchés ou fumés, sont les plus économiques que l'on puisse espérer et qu'en conséquence toute disposition qui conduirait à accroître le prix de vente du produit au consommateur serait voué à l'échec, malgré l'attrait indiscutable que représente le poisson présenté en l'état face à tout autre conditionnement, salé, séché, fumé ou en conserves appertisées.

Les techniques à retenir pour une installation de congélateur à terre devront tenir compte du fait que les produits congelés:

(a) seront consommés en l'état;
(b) seront de tailles et de natures variées;
(c) devront être conditionnés sous des formes variées.

La congélation à l'air en tunnel est donc à recommander avec éventuellement, en annexe, un dispositif de congélation par contact à plaques horizontales dans le cas où une partie des produits à traiter serait des crustacés, des filets, etc.

LA DISTRIBUTION ET LA CONSOMMATION DU POISSON CONGELE

Situation actuelle

La consommation du poisson congelé est surtout développée dans les pays anglophones (Ghana, Libéria, Nigéria, Sierra Leone) et, à un degré bien moindre, dans deux pays francophones (Dahomey, Togo). En 1964, le tonnage global de ce produit consommé en Afrique de l'ouest a été d'environ 55 000 t. Par ailleurs 90 000 t sont passées dans les entrepôts frigorifiques de l'Afrique de l'ouest si on considère les débarquements qui n'ont pas le caractère d'importation, c'est-à-dire ceux des flottes nationales et des flottes étrangères, thon inclus, et les importations des autres parties du monde.

Il faut comparer ce chiffre à celui du tonnage de poisson d'eau douce et de mer transformé en Afrique de l'ouest qui, pour la même année, a atteint en équivalent frais, 537 000 t.

La consommation globale en tonnes d'équivalent frais en 1964 a atteint: 787 000 t.

Par types de produit, cette consommation s'établit comme suit (arrondie à 1 000 t):

poisson frais	176 000 t
poisson congelé	55 000 t
poisson traité	537 000 t
poisson en conserve	19 000 t
	787 000 t

Le poisson congelé distribué en Afrique de l'ouest provient, pour une faible partie de pêche nationale moderne, la plus grande partie est issue de chalutiers étrangers sous contrat ou non.

Quel que soit le mode juridique d'introduction sur le territoire des Etats africains, le poisson est acheté par des sociétés modernes de distribution et il suit jusqu'au stade de demi-gros un circuit distinct de celui du poisson frais.

Ce circuit est une chaîne de froid incomplète aboutissant à la vente du produit décongelé dans les marchés africains généralement par les vendeurs traditionnels.

Au débarquement, les cartons de 20 à 30 kg de poisson trié sont entreposés dans des chambres froides à −18°C d'où la Société distributrice les répartit:

(1) vers les marchés du port de débarquement, par vente directe des cartons aux détaillants;
(2) vers les marchés des autres villes après transport par chargements complets de camions parfois isothermes jamais frigorifiques, vers des chambres froides relais mobiles ou de construction légère où il est repris en froid après le voyage et ultérieurement vendu aux détaillants toujours par cartons;
(3) vers les marchés secondaires des villages, soit par l'entreprise elle-même qui charge des camionnettes distribuant ses cartons dans plusieurs villages une ou plusieurs fois par semaine, soit par des acheteurs en demi-gros qui viennent au centre de distribution et repartent dans leur village avec un ou plusieurs cartons qu'ils revendent soit à d'autres marchands, soit directement aux consommateurs.

La chaîne de froid est interrompue au stade du demi-gros, lors de la vente des cartons aux femmes détaillants ou demi-grossistes par la société. Le poisson se décongèle lentement à la température ambiante. Les poissons entiers sont vendus finalement aux consommateurs pratiquement décongelés et ceux-ci les emploient comme le poisson frais. Les cartons ne sont en principe jamais réintroduits après leur vente dans les chambres froides.

Les invendus des détaillants se détérioreraient très rapidement s'ils ne pouvaient être transformés par fumage léger, ce qui est heureusement fait.

Ces dispositions, malgré la rupture de la chaîne de froid, donnent satisfaction sur le plan de la salubrité, car la consommation est immédiate.

Tout investissement supplémentaire condamnerait l'opération au détriment du consommateur; celui-ci en effet achète le produit avant sa complète décongélation et ceci dans la mesure où il doit le cuisiner immédiatement.

Chacun des Etats où ce système de distribution existe, a ses variantes particulières d'organisation de réseau.

Les prix sont fixés par les Sociétés jusqu'au stade du demi-gros à tous leurs points de vente et la politique menée par celles-ci varie suivant les circonstances:

(a) certaines tendent à l'égalisation des prix à l'échelle nationale en opérant la compensation du coût du transport et de l'entreposage secondaire à l'intérieur par une élévation du prix de vente à l'entrepôt principal;
(b) d'autres répercutent les coûts supplémentaires sur les prix aux différents stades de la chaîne;
(c) d'autres enfin établissent leurs barèmes de vente en fonction des prix courants du poisson frais sur le marché approvisionné.

C'est par ces méthodes que le débouché a pu progressivement s'élargir.

Le dernier aspect particulier de ces chaînes de distribution est leur souplesse. En effet, les petites chambres froides terminales de 5 à 10 t de capacité, sont facilement transportables et lorsque le volume des ventes s'est accru au-delà de la capacité de la chambre froide utilisée, celle-ci est remplacée par une chambre plus importante, tandis que la première est implantée dans une autre ville ou village où elle sert à la conquête du marché. Le réseau se complète de proche en proche. Lorsqu'après essai la Société constate que la demande est insuffisante pour justifier l'existence d'un dépôt, les installations sont retirées et remplacées par la desserte à jours fixes au moyen de camionnettes chargées au dépôt le plus proche.

Les situations dans les différents Etats ont été comparées au niveau des dépôts principaux des capitales (Salmon et Lagoin, 1967) (tableau 1).

Pour le poisson congelé, la différence entre les prix moyens provient de deux facteurs:

(1) variation des qualités des espèces dominantes:
en Sierra Leone: majorité de sardinelles, ethmaloses;
au Ghana: majorité de dorades et pagres;
(2) efforts de propagande et parfois vente au dessous du coût dans la capitale pour conquérir le marché (les prix sont inférieurs ou au plus égaux aux prix de vente au détail du poisson provenant d'autres sources d'approvisionnement.

Par contre, les marges sont plus fortes pour le poisson congelé par suite de bas prix consentis par les exportateurs pour conquérir le marché et concurrencer non seulement la pêche locale mais surtout les pays traditionnellement exportateurs (concurrence entre les Espagnols d'une part et les Japonais et les Russes d'autre part), mais aussi du fait que les frais de stockage, transport, etc., sont plus élevés que pour les autres conditionnements. Ceci indique que dans les conditions actuelles de production, seules des unités congélatrices à haut rendement permettent, sans avoir une rentabilité déficitaire, de présenter des produits à prix unitaire suffisamment bas pour répondre aux conditions du marché imposé par les importateurs.

Des unités modernes de pêche fraîche non congélatrices de plus faible productivité présenteraient un poisson d'un prix trop élevé pour supporter le coût de la congélation à terre, du stockage, etc., dans de telles conditions du marché.

TABLEAU 1. COMMERCIALISATION DU POISSON DANS LES DIFFÉRENTS ÉTATS

Etats		*Commercialisation en frais (unité F CFA/kg)*		
		Prix au débarquement	*Prix de vente au détail dans la capitale*	*Marge de commercialisation en %*
Sierra Leone	1	35	60	71
	2	46	73	58
	3	34,4	70	103
Libéria	1	43	81	88
	2	41	81	97
	3	40,5	80	97
Ghana	1	78	180	130
	2	70	180	157
	3	50	180	260
Togo	1	60	171	185
	2	—	—	—
	3	41,7	140	235
Dahomey	1	60	100	66
	2	65	100	54
	3	44	100	127
Nigéria	1	29	80	176
	2	40	70	75
	3	38,5	70	81

1 = Pêche traditionnelle.
2 = Pêche moderne (artisanale ou industrielle).
3 = Pêche industrielle: poisson congelé importé ou livré par des flottes sous contrat.

Il ne faut pas perdre de vue qu'en Afrique de l'ouest le commerce traditionnel de détail est le privilège presqu' exclusif des femmes, les hommes s'adonnant à la production, aux transports ou aux transactions en gros.

Le marché africain naturel est constitué d'un point de rendez-vous, place de terre battue quelquefois complétée par des abris rustiques où les femmes se livrent aux échanges.

Les produits sont disposés à même le sol sur de larges feuilles d'arbres devant les vendeuses. Le prix du service vente est normalement élevé, chaque vendeuse espérant subvenir à une grande partie des besoins de sa famille par les gains obtenus et étant prête à consacrer de longues heures à la négociation de faibles quantités de produits.

Avec l'apparition des villes ou bourgs, plus spécialisés dans leur rôle de marchés régionaux, la profession commerciale s'est mieux individualisée, les marchands se sont parfois groupés en sortes de corporations avec leurs règles et leurs dirigeants. C'est alors que purent être mieux aménagés les points de vente dans les marchés et souvent instaurées les taxes d'usage.

Il est parfois permis d'assister à une séparation complète des groupes de vendeurs: poisson frais, traité, etc.

Dans les grands marchés de redistribution coexistent les magasins des demi-grossistes et les stands des détaillants.

Partout, les installations fixes sont ou paraîssent insuffisantes, les règles d'hygiène qui pourraient être correctement respectées sont alors peu appliquées dès que les vendeuses débordent celles-ci.

L'affrontement de l'offre à prix élevé et de la demande à masse monétaire constante produit de fortes variations des cours en quelques heures et surtout pour le poisson frais ou congelé.

Le commerce traditionnel garde une part de jeu. Cependant, l'équilibre final s'établit de manière que les marchands tirent de leur activité un revenu généralement connu des autorités locales: 500 F CFA par jour de marché est un gain raisonnable en pays d'expression française, une livre ou 10 shillings suivant les cas en pays de langue anglaise, un ou deux dollars au Libéria.

Rares sont les marchands qui, leur gain minimum obtenu, ne sont pas tentés de clore leur activité du jour en soldant l'excédent de leur stock quotidien.

L'ensemble de tous ces facteurs tend à déprécier la marge moyenne de commercialisation du détail qui dépasse rarement 30 pour cent du prix de demi-gros dans les grands centres d'approvisionnement aisé.

Beaucoup plus restreinte est l'importance des marchands ambulants.

Le rôle des installations modernes, poissonneries avec meubles frigorifiques ou glacières et supermarchés est encore plus réduit puisque ce type de commerce s'adresse exclusivement aux classes aisées; il est cependant en expansion. Les transactions y ont lieu au poids, à prix fixe et les invendus sont généralement liquidés au marché traditionnel.

Les marges sont plus élevées, de 50 à 100 pour cent.

Le kilogramme de protéine-poisson peut donc varier pour des denrées similaires de un à quatre.

Il faut enfin remarquer que la fiscalité n'affecte que très peu le commerce de détail traditionnel alors que c'est le contraire pour celui qui fait appel à des techniques modernes.

Perspectives d'avenir

L'efficacité de la distribution du poisson est fonction de la durée des transports et de la forme de commercialisation.

Lorsque les villages de pêche traditionnelle ne sont pas reliés par de bonnes routes aux grands centres de consommation, le rayon de distribution du poisson frais ne dépasse pas les quelques kilomètres que peut parcourir à

pied le transporteur en deux ou trois heures. La demande dans la zone correspondante étant rapidement satisfaite, la plus grande partie doit être traitée par fumage ou séchage pour en assurer la conservation en vue d'une vente ultérieure, effectuée soit après un transport par pirogue, soit à l'occasion du passage d'un camion.

Par contre, dès que le village est desservi par une route bitumée les femmes des pêcheurs peuvent utiliser les transports en commun pour se rendre sur des marchés distants d'une cinquantaine de kilomètres. De plus, si le village a une production importante et s'il ne se trouve pas trop éloigné d'un centre de consommation, les mareyeurs peuvent venir y faire leurs achats en emportant avec eux la glace dont ils auront besoin. Ce dernier système de distribution s'est révélé particulièrement efficace au Sénégal où la zone de diffusion du poisson frais de mer présente des pointes marquées vers l'intérieur jusqu'à Tambacounda par exemple.

La réfrigération peut être utilisée aussi bien pour le poisson de pêche industrielle que pour le poisson de pêche traditionelle.

La réfrigération appliquée au poisson de pêche industrielle. Que la réfrigération fasse appel à l'eau de mer réfrigérée (procédé applicable aux sardinelles) ou à la glace (utilisable pour le poisson de fond), le poisson doit au débarquement être, soit trié, conditionné en caisse et reglacé avant son expédition, soit mis en resserre en chambre froide à 0°C (32°F).

Afin de maintenir la chaîne du froid sans rupture, les demi-grossistes des centres de distribution et les détaillants des marchés devront également disposer de chambres froides de resserre.

Les installations correspondant à cette chaîne comprennent donc:

(1) des chambres à 0°C aux ports de débarquement;
(2) de la glace en quantité suffisante pour satisfaire aux besoins des navires de pêche et à ceux des mareyeurs;
(3) des chambres froides de resserre au niveau des centres de distribution.

La réfrigération appliquée au poisson de pêche artisanale. La glace peut également être utilisée dans la distribution du poisson de pêche artisanale dès le débarquement des captures des pirogues, dans la mesure où le village de pêche est suffisamment bien relié au reste du pays par une route bitumée.

Le poisson ainsi conservé suit alors la même chaîne que le poisson de pêche industrielle.

A première vue, cette possibilité d'utilisation de la glace apparaît particulièrement importante en raison des pourcentages mis à terre par la pêche piroguière. Mais en fait, son emploi est soumis à certaines conditions qui limitent très sensiblement son intérêt.

Bien que pratiquée depuis longtemps en Afrique de l'Ouest, la réfrigération à l'aide de glace n'a, en effet, permis qu'une extension limitée de l'aire de distribution du poisson frais.

Cette limitation a pour facteurs principaux:

(1) la durée de conservation en pays tempéré du poisson à la glace, qui, pour que celui-ci soit acceptable sur le plan de la salubrité, n'est que d'environ 11 jours à 0°C (32°F), et huit jours à 3,5°C (38°F). Cette durée, bien que moins réduite pour les espèces capturées en eaux tropicales, reste un handicap sérieux. Si l'on prend par exemple la Côte d'Ivoire, on constate que sauf sur les petites unités, le poisson reste en glace à bord, sept jours en moyenne. Il ne reste donc plus que quelques jours au maximum pour le stockage au port de débarquement et le transport avant la vente dans les centres de distribution. Ce bref délai s'adapte mal aux fluctuations de la demande;
(2) la vente du poisson sous glace parvenu dans les centres de distribution doit être immédiate, la fabrication de glace n'étant pas généralisée dans les agglomérations de l'intérieur;
(3) les mareyeurs ne disposant pas de camions isothermes ou frigorifiques, leur rayon d'action est limité par la fusion de la glace au cours du transport, elle-même fonction de la température. C'est pourquoi la distribution sous glace n'a pu être correctement organisée que sur les axes routiers bitumés;
(4) l'état de fraîcheur du poisson mis en vente à l'intérieur n'est pas toujours satisfaisant: pour éviter une fusion trop rapide de la glace, celle-ci est cassée en gros morceaux. Par leur intermédiaire, les manipulations brutales et les cahots du transport sur les pistes provoquent des écrasements musculaires qui donnent un aspect peu attirant pour le consommateur, d'autant qu'en climat tropical la température des poissons disposés sur les étals à l'ouverture des marchés, voisine de 0° à 2°C dans les meilleures conditions, s'élève rapidement pour atteindre la température ambiante entraînant une altération beaucoup plus rapide du fait des détériorations "mécaniques" de la chair durant le transport;
(5) enfin, l'approvisionnement en poisson frais conservé sous glace est fortement compromis pendant les quelques mois de la saison des pluies durant laquelle les routes et pistes demeurent impraticables.

Ces différents inconvénients n'autorisent donc l'utilisation de la réfrigération par la glace pour la distribution intérieure que sous les conditions suivantes:

(a) existence de points de débarquement où les quantités débarquées sont suffisantes pour assurer le chargement complet d'un véhicule de mareyeur;
(b) existence d'une fabrique de glace sur ces points de débarquement ou à proximité;
(c) existence d'un bon réseau routier bitumé;
(d) existence de centres de consommation relativement proches des points de débarquement.

Jusqu'en 1963, la distribution du poisson de mer par transport sous glace était limitée à une étroite bande côtière ne présentant que quelques rares pointes vers l'intérieur (Bouaké en Côte d'Ivoire, Kumasi au Ghana, Tambacounda au Sénégal).

Depuis cette date, l'installation de réseaux de chambres froides à −18°C dans les pays anglophones, a permis une beaucoup plus vaste diffusion de poisson congelé d'importation ou de production nationale. C'est ainsi que

le poisson arrive maintenant jusqu'à Ganta (Libéria), Ilorin (Nigéria), Kénéma (Sierra Léone), Tamale (Ghana). Le succès que rencontre le poisson congelé incite les sociétés de distribution à améliorer leur réseau et l'on peut s'attendre à une importante extension de la zone de diffusion dans les années à venir.

La congélation du poisson présente des avantages aussi bien sur le plan de la technique de la distribution que sur celui de la qualité.

(1) Qu'il ait été congelé à bord dès sa capture, ou à terre après son débarquement, le poisson congelé est facilement stocké dans les entrepôts frigorifiques primaires, de relais ou de distribution. Cependant, le poisson stocké en glace une semaine à bord des chalutiers ayant déjà subi des modifications tissulaires, ne pourra pas être retenu pour la préparation d'un produit congelé de qualité. Les poissons même gras (type sardinelles) peuvent ainsi être conservés plus de deux mois à —20C° et plus de cinq mois à —30°C (—22°F), et les poissons maigres, deux mois trois semaines à —20°C et plus de six mois à —30°C.

Cette durée de conservation assure à la distribution à tous les niveaux une souplesse parfaite.

(2) Le conditionnement du poisson congelé facilite largement la manutention, le transport et la vente.

En Afrique de l'ouest, il est présenté en cartons de 20 ou 30 kg contenant chacun deux étuis de polyéthylène de 10 ou 15 kg. Cette présentation assure un coefficient élevé d'utilisation des chambres frigorifiques et rend aisé le chargement des camions ou des wagons utilisés pour les transports. Sortant des entrepôts à —20°C, chaque carton et à plus forte raison un chargement complet de cartons, représentent un volant de froid qui autorise des transports de plus de 10 heures sans utilisation de véhicules frigorifiques.

Parvenu aux centres de distribution il pourra, si la température du lot est encore suffisamment basse, être de nouveau stocké avec la même facilité en attendant la vente.

La vente aux détaillantes est rapide puisque, chaque carton ne contenant qu'une espèce déterminée d'un poids connu (20 à 30 kg), la pesée est inutile et la facturation pré-établie. Le transport au marché se fait plus facilement et dans de bien meilleures conditions hygiéniques, le poisson n'étant pas transvasé dans des cuvettes de propreté douteuse, ni exposé aux poussières de la route.

(3) La mise en place du réseau de chambres de distribution ne présente pas de difficulté.

Le débouché que représente l'agglomération choisie est étudié à l'aide d'une chambre froide démontable de faible capacité (10 t); selon les résultats obtenus, la chambre pourra soit être démontée pour être implantée dans un centre plus favorable, soit installée définitivement et complétée par d'autres chambres de même capacité ou par une chambre plus importante (50 t par exemple). Le réseau final pour une région comprendra outre l'entrepôt primaire au point de débarquement, un entrepôt relai de 100 à 200 t dans l'agglomération principale, permettant d'assurer rapidement et régulièrement l'approvisionnement de l'ensemble des chambres satellites de distribution. Il sera enfin complété par la desserte hebdomadaire et bi-hebdomadaire par camionnettes des villages situés dans un rayon d'une cinquantaine de kilomètres autour de chacune des chambres de distribution.

(4) Partout où il a été offert en Afrique, le poisson congelé a été bien accepté et la demande est en augmentation. Conservé en permanence à —20°C jusqu'à sa vente au consommateur, son état de fraîcheur après décongélation sur le marché est satisfaisant, quelle que soit la situation géographique du point de vente. Sa présentation est également supérieure à celle du poisson conservé à la glace car il est bien protégé dans son emballage de carton, il n'est ni écrasé par les blocks de glace, ni soumis aux fortes pressions dans les caisses surchargées entassées les unes sur les autres.

L'application stricte des principes de la chaîne du froid impliquerait que le poisson soit vendu congelé au consommateur qui pourrait éventuellement le conserver chez lui à l'aide d'un réfrigérateur domestique. En fait, faute d'installations appropriées sur les marchés africains, le poisson se décongèle lentement au cours de la vente. Il y a donc rupture de la chaîne de froid à ce niveau. Cette rupture ne présente pas d'inconvénient sérieux du fait que la ménagère africaine n'achète que pour ses besoins immédiats et prépare le poisson qu'elle vient d'acheter pour les repas de la journée ou le conserve par fumage à domicile. Cette pratique permet de très importantes économies par rapport aux frais d'investissements qu'entraînerait l'installation d'une chaîne complète du froid.

(5) Il se révèle enfin intéressant dans le domaine de son utilisation, dans toutes les zones où ne peut parvenir le poisson frais ou réfrigéré et qui n'étaient récemment encore approvisionnées qu'en poisson traité. Le poisson congelé se prête parfaitement à tous les modes de préparation culinaires utilisés pour le poisson frais (poisson bouilli, frit, etc.) et il peut également être fumé. Cette dernière qualité est d'ailleurs déjà largement utilisée pour la conservation des invendus jusqu'au marché du lendemain.

Le poisson traité correspondant au goût africain, il est prévisible que sa préparation artisanale traditionnelle se poursuivra; on peut cependant s'attendre à un très vif accroissement de la demande du poisson congelé qui offre une beaucoup plus importante gamme d'utilisations au consommateur. Au lieu d'être la seule forme de consommation, le poisson fumé ou séché n'en constituera plus qu'une parmi d'autres.

(6) Enfin, le succès qu'a rencontré le poisson congelé auprès des consommateurs tient également à ce qu'il ne coûte pas plus cher que le poisson de même espèce conservé à la glace. La distribution de ce dernier implique en effet l'utilisation d'emballages souvent perdus, le renouvellement de la glace au cours des transports ainsi que des frais de stockage de la glace sur les lieux de production de pêche artisanale.

La chaîne du poisson congelé devrait comprendre:

1°—des installations de congélation à bord (navires de pêche congélateurs) ou à terre (pour la congélation du poisson débarqué frais);
2°—des entrepôts frigorifiques de stockage aux ports de débarquement;
3°—des camionnettes ou camions frigorifiques;
4°—des chambres de relais ou de distribution à —18°C.

Les deux systèmes de commercialisation et de distribution qui existent parallèlement en Afrique de l'ouest sont adaptés aux types de denrées qu'ils diffusent.

Le système traditionnel basé sur l'identification du grossiste et du transporteur ou du détaillant et du transporteur s'applique aux biens de consommation de production locale vers les consommateurs locaux.

Production et consommation sont très fragmentées et jouent sur des quantités faibles aux deux extrémités du circuit.

Le système moderne au contraire s'applique à une production de masse qu'il s'agit de répartir sur des marchés de grosse consommation où les achats unitaires journaliers sont plus variés mais plus importants.

Il est impossible dans un supermarché de faire diviser la quantité unitaire offerte. Le poisson congelé s'achète en paquets de 100, 150 ou 250 g sinon 500 g. Entre le stade de la production et celui du détail, les transports s'effectuent autant que possible par envois de quantités correspondantes aux moyens utilisés, camions, camionnettes ou wagons complets, pour bénéficier des tarifs minimum, le groupage est employé pour bénéficier de ces tarifs lorsqu'il s'agit de lots divers.

Entre l'expéditeur, commerçant-stable et le réceptionnaire, lui aussi commerçant-stable disposant de magasins, la marchandise est confiée à un simple transporteur qui ne reçoit que le prix de son service.

En Afrique, ce dernier système ne fonctionne que dans un cadre restreint, entre les grandes compagnies importatrices et leurs comptoirs ou entre les importateurs des ports, les commerçants-stables de l'intérieur et ceux desservant la clientèle aisée des capitales et de quelques grandes villes.

Bien souvent les ventes de ces derniers commerçants s'adressent à des détaillantes africaines qui, elles-mêmes, revendent sur les marchés par fractions "l'unité" acquise dans le magasin.

La distribution du poisson emprunte le circuit moderne d'une part pour une partie de la commercialisation au détail dans les classes aisées, poissonneries modernes, supermarchés et, d'autre part, pour la commercialisation jusqu'au stade du demi-gros des denrées importées y compris le poisson congelé.

Ce n'est qu'en complément d'approvisionnement de la chaîne de distribution du poisson congelé constituée dès 1962, qu'en 1964 au Ghana et 1966 au Nigéria, sont venues s'ajouter les productions des navires congélateurs nationaux armés dans le but de diminuer progressivement les importations.

Aussi l'extension du marché du poisson par le système moderne parait-elle liée à deux conditions complémentaires:

(1) l'existence d'un pouvoir d'achat disponible dans une population suffisamment concentrée pour qui les investissements afférents à la distribution moderne puissent être rentabilisés;
(2) l'absence d'un réseau concurrent de distribution traditionnelle de poisson frais ou traité, satisfaisant totalement aux besoins des consommateurs.

En dehors des pays de production insuffisante et comportant des zones économiquement développées, côtières ou plus éloignées du littoral, tels le Ghana, le Nigéria, la Sierra Leone, le Libéria, le Togo et le Dahomey où sont déjà apparus des systèmes modernes de commercialisation du poisson congelé, on recherchera d'abord l'amélioration du système traditionnel. On ne tentera qu'à titre expérimental l'introduction prudente d'un réseau moderne pour ne pas bouleverser l'équilibre interne des revenus (cas de la Côte d'Ivoire et du Sénégal par exemple).

Dans cette optique, il apparaît que le poisson de mer congelé doit permettre un accroîssement de la consommation du poisson dans les zones éloignées de la côte, particulièrement dans la zone intermédiaire entre la zone d'extension du poisson frais de mer et la zone d'extension du poisson frais d'eau douce, à condition que la densité de la population le justifie et que ses moyens monétaires atteignent un seuil égal à celui des zones de consommation du poisson frais de pêche traditionnelle.

La confirmation du succès de son implantation ne peut venir que de la recherche de la suppression du maximum de solutions de continuité entre le producteur et le consommateur.

Dans ce sens, l'entreprise de pêche ou l'importateur devrait posséder ses propres moyens de conditionnement, de stockage et ses comptoirs de vente en demi-gros avec, éventuellement, dans les grandes villes, ses magasins de vente au détail, encore que pour ce stade il semble prématuré de vouloir court-circuiter les dispositifs traditionnels.

CONCLUSIONS

De récentes études (Salmon et Lagoin, 1967) ont montré que, compte tenu de l'évolution démographique et de celle du niveau de vie, la consommation globale de poisson en 1970 dans les 14 pays de l'Afrique de l'Ouest devrait être de 998 000 t dont 772 000 t de poisson de mer et 226 000 t de poisson d'eau douce. Par rapport à 1964 l'accroissement est de 211 000 t dont 185 000 t de poisson de mer.

L'examen des plans de production montre (pour le poisson destiné à l'alimentation humaine) que pratiquement la balance des échanges avec le reste du monde devrait s'améliorer de 294 000 t à 207 000 t de poisson Par contre, étant donné les exportations vers le reste du monde par les pays africains excédentaires, en fait, le déficit global de l'Afrique de l'ouest pour sa consommation serait de 304 000 t contre 250 000 t en 1964. L'accroissement des besoins devrait donc se traduire par une augmentation de 54 000 t des importations en provenance du reste du monde, car les Etats africains excédentaires sont à même de fournir 40 000 t environ, dont 18 000 t de poisson congelé, pour la satisfaction partielle des besoins des Etats déficitaires qui devraient importer 94 200 t de plus qu'en 1964.

Si, pour tenir compte de la conjoncture, on admet que l'accroissement de la consommation du poisson congelé se maintiendra au moins à son niveau actuel, on peut espérer qu'il représentera 10 pour cent de la consommation globale en 1970, soit environ 100 000 t contre 55 000 t en 1964.

Un tel objectif se justifie lorsque l'on connaît l'engouement des populations pour le poisson congelé. En effet, pour elles il représente plus un aliment qu'un condiment

alors que traditionnellement ce rôle était dévolu au poisson transformé qui seul pouvait jusqu'à ces derniers temps, atteindre le consommateur situé à quelque distance du point de débarquement de la pêche.

La pratique de la congélation a l'avantage de permettre de présenter au consommateur un produit dont l'aspect, l'odeur et le goût sont identiques à ceux du produit récemment tiré de son milieu naturel.

Cependant un certain nombre de conditions sont impératives pour assurer le développement de la consommation du poisson congelé:

(1) la nécessité d'offrir au consommateur un produit de première fraîcheur, ceci suppose donc un traitement très soigné à bord et sauf cas particulier où les marées ne dépassent guère 48 heures, le recours à la congélation sur le navire même.

Cette congélation à bord implique l'existence au port de débarquement de structures d'accueil adaptées et sur les grands axes de commercialisation, des conditions de transports et de stockages appropriées.

Etant donné les risques de rupture des charges et la méconnaissance générale des conditions d'utilisation du froid chez les commerçants traditionnels, il est difficilement pensable que l'on puisse se passer d'organisations intégrées, de la production au stade demi-gros, pour assurer la distribution du poisson congelé dans les pays de l'Afrique de l'ouest;

(2) le facteur prix apparaît déterminant puisque précisément le poisson congelé doit pouvoir atteindre des catégories de consommateurs incapables d'acquérir d'autres sources de protéines animales du fait de leur faible pouvoir d'achat.

Ceci suppose donc:

(a) que les coûts de production soient abaissés au maximum, grâce en particulier à des péréquations que permettrait l'exportation d'espèces recherchées par les pays fortement industrialisés d'Europe et d'Amérique;

(b) que les coûts de distribution soient les plus faibles possible, l'incidence de la mise en oeuvre d'un circuit du poisson congelé ne devant pas surcharger outre mesure le coût du circuit traditionnel.

Dans une telle optique, il apparaît que pour toutes les espèces industrielles susceptibles d'être transformées avant consommation, la congélation en saumure à bord s'impose, dans tous les autres cas la congélation devrait s'effectuer au moyen de congélateurs à plaques verticales ou horizontales, fonction du type de produit à traiter.

Les installations frigorifiques au port de débarquement devraient être essentiellement des entrepôts de stockage de produits congelés. Seule une faible partie des installations comporterait quelques chambres à 0°C (32°F). Une fabrique de glace et les chambres de stockage pour la glace y seraient adjointes. Ces dispositions complémentaires seront dimensionnées en fonction de la seule pêche traditionnelle ou moderne destinée au marché local. Enfin, il serait prévu un atelier de conditionnement éventuel pour les produits particuliers destinés à l'exportation (filetage).

Il est important que les deux secteurs pêche fraîche et pêche congelée soient nettement séparés, le volume des produits traités, leur nature et leur destinée étant beaucoup trop différentes pour que les deux circuits soient confondus.

L'étatdes voies de communication et la dispersion des points de vente de détail ne permettent pas d'envisager dès à présent l'utilisation de camions ayant leur propre source de froid pour la distribution des produits congelés des entrepôts relais aux détaillants.

Seuls devraient être utilisés des camions isothermes dont le produit jouerait le rôle de source de froid. Ceci ne peut être valable que parce qu'avant décongélation complète, le poisson est commercialisé pour être utilisé rapidement dans une préparation culinaire chez le consommateur.

Par contre les entrepôts relais ne devraient être installés que si les moyens de communication permettent l'utilisation de camions produisant eux-mêmes le froid nécessaire à la conservation des produits transportés à une température voisine de −18°C.

En aucun cas ces entrepôts relais ne devraient être définitifs et onéreux. Une grande souplesse doit présider à leur utilisation. Facilement transformables ils devraient pouvoir être aisément soit agrandis, soit déplacés. Les coûts de leur amortissement et de leur fonctionnement devraient être les plus bas possible.

L'engouement du consommateur africain pour le poisson congelé devrait permettre rapidement dans l'avenir de couvrir les besoins de toutes les zones qui possèdent peu de troupeaux d'animaux pour satisfaire leurs besoins en protéines animales notamment par suite des maladies infectieuses et parasitaires qui en rendent l'élevage très difficile et qui par ailleurs sont difficilement atteintes par les poissons transformés issus de la pêche traditionnelle ou artisanale moderne de mer ou d'eau douce.

Mais, il ne faut pas perdre de vue que pour l'ensemble des Etats de l'Afrique de l'ouest, les besoins physiologiques théoriques minimum en protéines d'origine animale ne sont couverts en moyenne en 1966 qu'à environ 68 pour cent et que seulement dans quatre d'entre eux la couverture de ces besoins atteint ou dépasse 100 pour cent.

Etant donné les limites d'accroissement du cheptel, c'est à la mer qu'il est demandé de combler du déficit.

Le traitement des produits de la mer par la congélation apparaît désormais une solution pratique que ce soit à la production ou pour le stockage et la distribution d'un produit dans un état le plus voisin possible de son état naturel. Ceci représente un immense progrès dans l'amélioration indispensable de la nutrition de toutes les couches des populations africaines.

Bibliographie

ALDRIN, J F 1966 Expérimentation sur la congélation en saumure. Direction des Pêches Maritimes et Lagunaires, Rep. de la Côte d'Ivoire. Octobre.

SALMON, G et LAGOIN, Y 1967 Etude technique et économique comparée de la distribution du poisson de mer dans les pays de l'Ouest africain, Secrétariat d'Etat Français aux Affaires Etrangères chargé de la Coopération.

DISCUSSION

Kreuzer (FAO): I would like to draw attention to the fact that since freezing of fish has now been introduced into many tropical developing countries, there is a definite need for economic studies of the practical aspects to decide on the form in which it can be developed. In many tropical countries they do not use freezing techniques, as we do in Europe, to retain as much as possible the original flavour and textural quality of the fish. Freezing is just used to preserve the fish. It is put in a cold store, at approximately −10°C (+14°F), slowly frozen, then transported without any refrigeration over long distances through the tropics, again put in a cold store and then sold in the market in a frozen state. It is satisfactory because the consumer uses this fish only in small portions as a condiment rather than as a food and therefore the texture is not important. Freezing is just used for the prevention of spoilage. The fish could not be brought from the lake to the consumer centre in any other form.

In West Africa, countries with no facilities for freezing buy frozen fish from Russian, Japanese, Polish and other foreign vessels, store it more or less properly in cold stores and then distribute it as fresh fish. It is even sent 400 or 500 km inland without refrigeration. Here again, freezing is used to preserve the fish instead of ice which is not available. The product will be acceptable to the consumer as long as his food habits do not change. However, economic studies should be made to determine what types of product and what types of process will be practical without damaging the consumer market for the future. This is very important, because present practices in tropical countries disregard many of the advantages of freezing, and use it only as a short-term preservation process.

Malick Dia (Sénégal): A la suite de l'intervention de M. Kreuzer, je m'excuse de prendre la parole pour dire combien ces aspects économiques de la congélation du poisson sont importants pour nos pays de la zone ouest africaine et pour donner quelques compléments d'information sur la commercialisation des produits congelés dans ces pays.

D'abord je dirai que nous effectuons la congélation du poisson en utilisant les mêmes techniques que dans les pays européens. Différentes installations frigorifiques sont en place dans les ports des principaux pays de pêche comme le Sénégal, le Ghana, etc. Ces installations sont d'ailleurs utilisées par les navires des pays européens qui croisent dans la région.

Au Sénégal nous congelons soit en tunnel à air pulsé, soit en saumure, des poissons de différentes espèces démersales ou pélagiques pour les besoins de notre marché national ou pour l'exportation dans les pays africains. C'est ainsi que nous congelons et exportons sur le Ghana des poissons de l'espèce *Sardinella aurita* qui sont ensuite expédiés par navires congélateurs. Le courant qui est amorcé est riche de promesses pour le développement de nos pêches et pour les échanges inter-africains.

S'agissant de la distribution sur la marché national, nous avons des problèmes. En effet, les structures de congélation et d'entreposage se trouvent sur la côte. Pour porter le poisson dans les agglomérations de l'intérieur, le problème des prix intervient car le pouvoir d'achat des populations décroît à mesure que l'on s'égoigne de la côte.

Le poisson est décongelé et transporté en camions simples sous glace, avec transport de nuit pour mettre à profit la fraîcheur des nuits.

Le poisson arrive en bon état sur les marchés et il est distribué immédiatement après aux consommateurs. Naturellement et dans bien des cas il ne présente pas les excellentes qualités du poisson congelé vendu en Europe occidentale, mais il convient bien à l'usage des consommateurs de nos pays.

Par contre les produits, comme les soles, les crevettes, les langoustes qui sont des produits d'exportation vers les marchés riches exigent de nous des précautions plus coûteuses. Nos industriels ont su s'adapter car nous disposons d'installations de première qualité qui font de la surgélation et donnent des produits qui ont conquis droit de cité sur les marchés les plus difficiles. A titre d'exemple, je vous citerai la sole congelée au Sénégal sous la marque IGLOO qui se vend bien en Belgique et aux Pays-Bas.

Nos efforts de modernisation des équipements vont dans le sens de notre progrès économique, par l'acquisition des moyens techniques les plus modernes.

Kreuzer (FAO): I would like to ask the last speaker about the purchasing power of the population. Can you tell us what proportion of the population use frozen fish in Senegal, what amount of fish will probably be frozen and what part freezing will play in the future development of the fishing industry in your country.

Malick Dia (Sénégal): En ma qualité de responsable des productions maritimes du Sénégal, je puis vous répondre d'une façon assez précise.

A la fin de 1966, notre production globale de pêche a été évaluée à 146.000 t de produits. Ce chiffre comporte naturellement environ 10.000 t de poissons "industriels", les thons qui arrivent et qui sont traités et mis en conserves pour l'exportation dans nos usines de conserveries à Dakar. Le poisson de marée comprend 96.000 t, qui sont entièrement consommées au Sénégal sous la forme de poissons frais ou congelés.

La pêche artisanale sénégalaise est une pêche saisonnière. Du mois de juillet à fin septembre, de nombreuses espèces démersales et pélagiques se raréfient avec l'apparition des pluies et il devient nécessaire de constituer des réserves de "soudure" pour l'approvisionnement des populations. Environ 30.000 t de poissons divers sont traités par les méthodes de conservation par le froid et particulièrement par la congélation pendant les périodes de grosse pêche.

La distribution est ensuite effectuée à la population par l'usage de camions, le poisson étant décongelé et mis sous glace ou vendu directement congelé à une bonne partie de la population qui l'accepte sans aucune réticence, principalement dans les grandes villes.

Naturellement, pour la distribution à l'intérieur du pays où le faible pouvoir d'achat des populations n'est pas en faveur du poisson congelé qui coûte un peu plus cher, des problèmes se posent. L'Etat est intervenu et dans les cas de distribution de réserves de soudure, une caisse de péréquation permet d'indemniser les distributeurs de façon à maintenir un niveau de prix compatible avec les moyens des acheteurs.

Dans les années à venir, nous comptons organiser notre marché du poisson grâce à une amélioration sensible des structures d'accueil et de commercialisation du poisson et nous sommes convaincus alors que le poisson congelé trouvera un placement certain auprès des populations de l'intérieur.

Je termine en disant que le reste, soit 40.000 t, est réparti entre l'artisanat des produits locaux (poissons fumés, séchés, salés, etc.) l'autoconsommation des populations riveraines et les produits d'exportation.

Watanabe (FAO): It is feasible to freeze freshwater fish from the lakes in Zambia economically. I have been there since 1965 and I have observed that the freezing industry has been in operation despite rather high production cost. It is interesting to note that frozen fish are sold in the market at higher price than iced fresh fish. Local people pay more for it and the demand for frozen fish is still increasing.

Sepić (Canada): There are many other problems besides the application of proper freezing techniques which require solution in order to keep the freezer vessel industry on a profitable basis. Ranken has already mentioned that problems

of proper handling are even more important than problems of freezing. These are even more complex problems.

I might mention one situation with which I am familiar. It concerns the long-line fishing and freezing tuna at sea off the West Coast of Africa, during the period 1959 to 1965. The fish were exported to many European countries, principally for canning.

During this period the number of vessels participating increased from 30 to more than 180, while the average catch per vessel decreased from 8 to 3.5 or even 3 t per day. Although the same sharp freezing technique was used, the quality gradually deteriorated. This was due to the taking of poorer quality fish from new grounds, the transportation of the frozen fish from the grounds in refrigerated cargo vessels, many of which were not well suited for the purpose, the additional handling because of this transhipment and the modification of fishing gear.

At the same time the prices for the frozen fish greatly increased—in one instance from less than U.S. $250 to more than U.S. $400 per ton. By increasing its productivity and developing products at higher value, the canning industry was able to absorb this increase, but it seems unlikely that they will be able to accept any further rise in the prices of fish. The fact that brokerage fees have fallen from 8 to 3.5 per cent suggests that the fishing companies' profits have also decreased

It appears that a marginal profit situation led to some steps being taken which resulted in poorer quality products. It seems to me that in this case, a restriction on the number of fishing vessels in the area coupled with avoidance of grounds where the fish is of poor quality and proper attention to handling and transport operations would have a greater bearing on the profitability of the operation than improvements in the freezing and storage practice.

Seliber (U.S.A.): I would like to point out the possibility of horizontal integration by local fishermen or cooperatives for the purpose of producing cryogens such as liquid nitrogen. Liquid nitrogen would be used both for freezing and transport. In the U.S.A. there are now approximately 6,000 LN trailer and truck installations, and I have been advised that in Europe the number is 3,700. This method of refrigerated transport has proven its simplicity and should be well suited for developing nations. Similarly the resistance of cryogenic freezers to the maintenanceproblems inherent in conventional freezing in a high humidity and high temperature environment, indicate their applicability to the tropics.

Thus for a number of reasons cryogenic technology should be very closely examined. Among the many variables in establishing true costs is the cost of energy. Approximately 0.60 kWh of energy per kilogram (0.27 kWh/lb) is required to produce liquid nitrogen. This is a practical number and depending upon the cost of electricity in a community, will be a major factor in the delivered price of liquid nitrogen. However, the cost of energy, significant as it is, is still secondary to the processing and handling costs. Cryogenic material lends itself to integrating into an overall production-transport system for fish. I know of no technique that is available today, which offers so much promise for local fishery development. Fishery products for export, as well as local consumption, can be produced from a variety of fishery resources.

Role of Product Development in the Rational Utilization of Fishery Resources, with Particular Reference to Freezing Fish at Sea

by R. Kreuzer

Role of product development in the rational utilization of fishery resources, with particular reference to freezing fish at sea.

A substantial increase in fish landings within the next 30 years will be necessary to provide more food and essential nutrients. Equipment and techniques are available to fish all oceans. Improvements and new developments will enable the preservation of heavily increased catches. In this connection, freezing fish at sea plays an important part and irradiation at sea is under development.

The problem, however, remains how to make available for direct human consumption increased landings and fish species less suitable for the fresh or frozen-fish market. In the light of this, the necessity for product development is emphasized. However, this development in connection with the rational utilization of the fishery resources will require planning and assistance by governments and international organizations and full collaboration from industry.

Freezing fish at sea can ensure products acceptable to the consumer only if recently available knowledge is intelligently applied. Freezing fish of the freshest quality does not necessarily ensure that products of acceptable eating quality will reach the consumer's table, even if optimal storage conditions are applied. The condition of fish, handling before freezing and freezing time in relation to *rigor mortis* should be taken into consideration.

The mere production of frozen fish is not sufficient to ensure consumption. Marketing problems connected with quality and with the various forms in which frozen fish is landed, demand a closer relation between processing and marketing. Quality control should aim at encouraging better processing rather than at controlling the end product.

Importance de la mise au point de produits de la pêche nouveaux dans l'utilisation rationnelle des ressources halieutiqués avec reférence spéciale à la congélation du poisson en mer

Une augmentation substantielle des quantités de poisson débarquées dans les 30 prochaines années est nécessaire pour fournir davantage de nourriture et d'aliments essentiels. L'équipement et les techniques existent pour pêcher dans tous les océans. Des améliorations et de nouveaux développements des techniques permettront de conserver des prises considérablement augmentées. A cette fin, la congélation du poisson en mer joue en rôle important et l'irradiation en mer est en cours de développement.

Reste à savoir, cependant, comment rendre directement disponibles à la consommation humaine les quantités accrues de poisson débarquées et les espèces de poisson peu aptes à la commercialisation à l'état frais ou congelé. Dans cet ordre d'idées, il convient d'insister sur la nécessité d'élaborer de nouveaux produits. Cela, de même que l'utilisation rationnelle des ressources en poisson, demande à être planifié avec l'assistance des gouvernements et des organisations internationales et la pleine collaboration de l'industrie.

La congélation du poisson en mer ne procure des produits acceptables pour le consommateur que dans la mesure où les connaissances récemment acquises sont appliquées intelligemment. La congélation du poisson de première fraîcheur n'assure pas nécessairement un qualité convenable des produits qui atteindront la table du consommateur, même si les meilleures conditions de conservation ont été appliquées. L'état physiologique du poisson, la manière dont il a été manipulé avant la congélation et l'époque à laquelle il a été congelé par rapport à l'évolution de la *rigor mortis* doivent être considérés.

La simple production de poisson congelé ne suffit pas à assurer la consommation. Les problèmes de commercialisation étant liés à la qualité et aux différentes présentations sous lesquelles le poisson congelé est mis à terre, des relations plus étroites entre la fabrication et la commercialisation sont souhaitables. Le contrôle de qualité doit viser à encourager une meilleure fabrication plutôt qu'à contrôler le produit final.

Importancia del desarrollo de productos pesqueros en la utilización racional de estos recursos, con referencia especial a la congelación del pescado en el mar

Un aumento sustancial de los desembarques de pescado en los próximos 30 años, será necesario para proveer más alimentos y nutrientes esenciales. Se dispone de equipos y técnicas para pescar en todos los océanos. Mejoras y desarrollo de nuevos métodos permitirán la preservación de capturas muy superiores a las actuales. A este respecto la congelación de pescado en el mar juega un papel importante y la irradiación en el mar está en desarrollo.

Persiste, no obstante, el problema de cómo poner a disposición, para el consumo humano directo, mayores cantidades desembarcadas y especies menos apropiadas para el mercado fresco y congelado. En base de estos hechos, la necesidad de desarrollar productos se hace imprescindible. No obstante, este desarrollo, en relación con la racional utilización de los recursos pesqueros, requerirá planificación y asistencia por los gobiernos y organizaciones internacionales y una total colaboración de la industria.

La congelación del pescado en el mar puede asegurarnos productos aceptables para el consumidor, solamente si los recientes conocimientos disponibles son aplicados inteligentemente. Congelar pescado de la más fresca calidad no nos asegura necesariamente que el producto obtenido sea de calidad aceptable para el consumidor, aún en los casos donde las condiciones de almacenamiento aplicadas sean óptimas. La condición del pescado, su manipulación antes de la congelación y el tiempo de congelación en relación con el *rigor mortis*, deben ser tenidos en cuenta.

La mera producción de pescado congelado no es suficiente para asegurar el consumo. Problemas de mercado, vinculados con la calidad y las diferentes formas en que el pescado congelado es desembarcado, exigen una más estrecha relación entre los procesos industriales y la comercialización. El control de calidad debe contemplar la necesidad de perfeccionar estos procesos, más que a controlar el producto final.

DIMINISHING fish stocks in traditional fishing grounds and expansion of territorial waters have compelled many nations to venture further for suitable raw materials and to explore new fishing grounds. Increasing the duration of the voyage demands, in turn, large vessels and more effective preservation of the fish than ice can offer. Consequently, long distance fishermen were urged to take processing equipment right to the fishing grounds.

Long distance fishing fleets and the development of fish processing at sea are, therefore, main characteristics of the modern fishery industry. As a result of this development, landings increased rapidly during recent years and salting of fish, for centuries the only processing operation carried out at sea, is being steadily replaced by freezing, canning and reduction at sea. At the same time, the number of fish species being processed, including frozen, at sea has increased considerably, so that many new fish

species and new products are landed and offered at the markets. The increased landings of processed fish have made marketing a key factor in the economic planning of fishery development.

A further increase in production of possibly as much as 50 million tons/year may be physically feasible during the next 20 to 30 years. The fact that a major portion of this would have to be marine fish and shellfish, not at present readily acceptable to man, raises the question of how it can be converted into a useful and marketable form. This indicates the urgent need for further advances in the technology of fish utilization and product development and for new approaches in marketing and distribution if the capacity of the marine fishing fleets is to be fully utilized. The operation of large modern fishing fleets has made product development and marketing, in all their various aspects, focal points in the rational utilization of fishery resources.

PRESENT AND POTENTIAL SEA FISHERY RESOURCES

According to FAO statistics (table 1), nearly 50 million tons of marine fish and shellfish were landed in 1966. Pelagic fish, such as herrings, sardines, anchovies and related species, are the main types caught in world fisheries. The production of these species has increased steadily since 1958 and, in 1966, reached a volume of 18.66 million tons, which represents about one-third of the total world catch of 56.8 million tons. Fish of this group are mainly used for reduction to fish meal and, to some extent, for canning, marinating, salting, etc.

Ranking next in volume are cod, hake, haddock and related species. The landings of these fish, which in the North Atlantic are most important for the fresh fish market and as raw material for the freezing, drying and salting industries, in 1966 amounted to 7.27 million tons. Next in volume come red fishes, basses, congers, etc., amounting to 3.19 million tons, jack mackerels, mullets, etc., to 2.02 million tons, mackerels, billfishes, etc., to 2.00 million tons and tunas, bonitos and skipjacks to 1.32 million tons; the latter group being extremely important for the freezing and canning industries. The landings of flounders, halibuts, soles, etc., and of sharks and rays were 1.09 and 0.43 million tons respectively. In addition, the following were landed: unsorted and unidentified marine fish, 7.95 million tons; crustaceans, 1.26 million tons; molluscs, 2.91 million tons and sea cucumbers, sea urchins, etc., 0.04 million tons.

The present main fishery resources are shown in fig 1. About half of the world catch comes from the Pacific

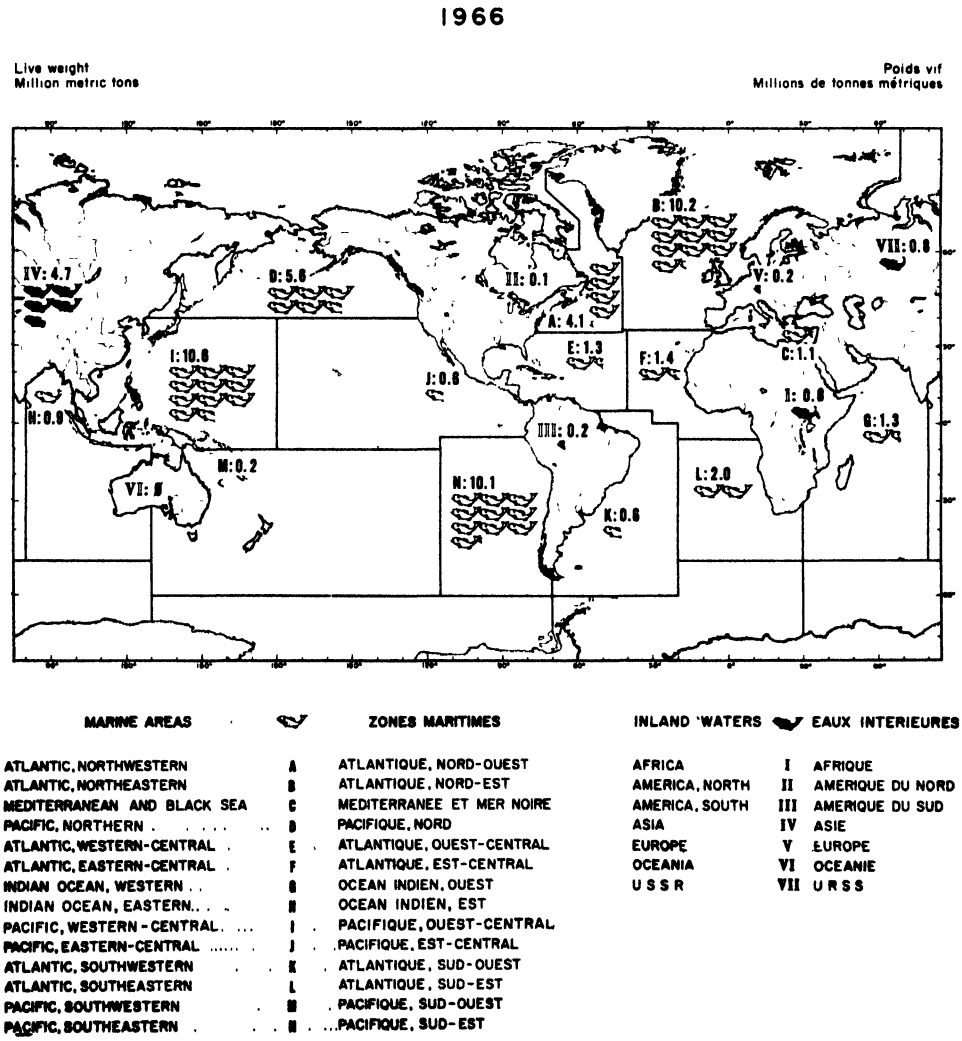


Fig 1. World catch by major fishing areas

Ocean with the main fishing areas in the north-western and south-eastern part. The Atlantic Ocean contributes about 39 per cent, principally from the traditional fishing grounds in the north-eastern and north-western Atlantic. The Indo-Pacific area supplies less than 5 per cent of the total world catch.

TABLE 1. WORLD CATCH OF MARINE FISHES, CRUSTACEANS, MOLLUSCS AND OTHER INVERTEBRATES (BY GROUPS OF SPECIES) IN MILLION TONS (LIVE WEIGHT)

	1956	1966
Flounders, halibuts, soles, etc.	0.68	1.09
Cods, hakes, haddocks, etc.	5.12	7.27
Redfishes, basses, congers, etc.	2.06	3.19
Jacks, mullets, etc.	1.43	2.02
Herrings, sardines, anchovies, etc.	6.78	18.66
Tunas, bonitos, skipjacks	0.88	1.32
Mackerels, billfish, etc.	0.88	2.00
Sharks, rays, etc.	0.33	0.43
Unsorted and unidentified marine fishes	4.15	7.95
Crustaceans	0.91	1.26
Molluscs	1.94	2.91
Sea cucumbers, sea-urchins, etc.	0.04	0.04
	25.20	48.14

Source: FAO, *Yearbook Fish. Statist.*, vol. 22, 1967.

PRESENT UTILIZATION OF THE WORLD CATCH

Table 2 shows the trend in the disposition of the world catch between 1956 and 1966. During this period there was a substantial increase in freezing of fish and a remarkable decrease in fresh fish marketing and in curing. It is interesting to note the quantity of fish used for reduction to fish meal. As shown in table 1 the increased landings of herring, sardines, anchovies, etc., are mainly responsible for the increase in world catch of marine fish during the period under consideration. These species are used for reduction to fish meal rather than for direct human consumption. The catches of anchoveta (*Engraulis ringens*) made Peru the world's first fishing nation and the largest producer of fish meal. In 1966, about 8.5 million tons of achoveta were landed in Peru, almost all of which were reduced to fish meal.

TABLE 2. DISPOSITION OF WORLD CATCH (PERCENTAGE)

	1956	1966
Marketing fresh	42.4	31.7
Freezing	7.3	12.3
Curing	24.0	14.3
Canning	9.5	8.8
Reduction	13.5	31.2
Miscellaneous purposes	3.3	1.7

Source: FAO, *Yearbook Fish. Statist.*, vol. 23, 1967.

EXPECTED COMPOSITION OF FUTURE LANDINGS

The Indicative World Plan (IWP) Working Group on Marine Resources Appraisal at its meeting in Rome in December 1966 gave a preliminary account of the potential fishery resources based on the information available from 16 areas. The meeting concluded that the stocks of demersal fish species, especially all those which at present have consumer preference in many countries, are in general heavily exploited. Only a few demersal species, mainly redfish and hake, are thought to be significantly under-exploited in some ocean areas. Some increase in landings could be gained from the fuller exploitation of these stocks. Species accounting for the greatest increase in world fish landings will, however, include anchovies, sardinella, mackerel, horse mackerel and herring, as well as dogfish, sharks, rays, capelin, lance, argentines, grenadiers and small deep-sea fish which seem to extend over wide areas of the world's oceans. These small fish seem to be less than 5 cm long and very thinly scattered.

The greatest source of edible protein are the low trophic organisms of the ocean. While phytoplankton cannot be harvested economically, there are herbivores and first-stage carnivores large enough to be harvested with present technology. In this connection, the krill stocks from the Antarctic should be mentioned. These stocks may yield between 100 and 500 million tons annually; however, for economic reasons only particularly dense populations are accessible to fishing operations.

From the information at present available, it is apparent that increased effort to harvest both under-exploited and unexploited marine resources would result in increased landings of those species which are at present either mainly used for the production of fish meal or are hardly used at all.

NEED FOR PRODUCT DEVELOPMENT AND TECHNOLOGICAL ADVANCES IN UTILIZING FISHERY RESOURCES

Although it is quite generally accepted that fishery resources can contribute substantially to man's future food requirements, there is some uncertainty as to how many of the presently underexploited or unexploited fish stocks can be used to the fullest extent for human nutrition within the next few decades. The fact that a major part of the future landings would have to be marine fish and shellfish at present unacceptable to man raises the question of how it can be converted to a useful and marketable form. No doubt the future increase in demand for fish meal will require some part of these increased supplies, but it will be necessary to look to a significant increase in quantities to be used for direct human consumption.

The fishing industry must, therefore, learn how to utilize, on an economic scale, fish species which do not readily lend themselves to direct consumption by man. The problem may possibly be solved by using stocks of small fish for reduction to fish meal, if production is economic, thus making available for human consumption at least some of the large pelagic fish stocks which are presently being converted to meal.

Special efforts are essential in the field of product development to meet changing consumer tastes, the demand for diversified fish products and the need to compete with other food products. By far the most important reason, however, is to have the means to use all kinds of fish and shellfish to feed the growing world population and to contribute to the supply of urgently needed protein. To this end greater attention must be given to the use of fish as a low-cost food for low-income population groups and as a protein supplement for diets of low nutritive value. Such development will involve new approaches to distribution and marketing of fishery products.

In connection with the latter development, there is also an urgent need for further advances in the technology of fish preservation on a large scale. Insufficient attention and support is being given to the development of techniques for the quick and efficient preservation of large quantities of fish for human consumption. With the present methods of preserving fish for use as food, the quantities which can be handled quickly enough to avoid quality losses and spoilage are limited. The techniques developed for the manufacture of fish meal for animal feeding, at present, provide the only means of preserving and processing very large landings of fish that can be caught at low cost and thus permit economic utilization of millions of tons each year. The fact that similar means have not yet been developed for the economic utilization of very large landings for human consumption is a challenge for governments and those who have responsibility for exploiting fish resources for the growing world population. As fish products most suitable as protein supplements, etc., will mainly be in powdered form, quick freezing at very low temperatures, or preservation of minced fish by means of solvents, could probably be applied. Suitable preservation methods need to be developed for use on board ships to allow the preservation of raw material on a large scale at low cost. Irradiation of fish may also become practicable for the quick preservation of large catches at sea.

At the International Conference on Fish in Nutrition in 1961, it was recommended that in planning research and development programmes for better utilization of fishery resources, attention should be given, not only to new processing techniques, but also to improvement of methods already in use, such as canning, freezing and certain other processes which have unique technological characteristics and social or economic implications. Attention was drawn to the fact that more is known concerning the nutritional value of fishery products fed to mink and chickens than concerning the nutritional value of fishery products eaten by man. The Conference recommended that scientists working on processing methods and nutritional aspects of all types of fishery products should be encouraged to participate in future work of this kind (FAO, 1962).

ROLE OF GOVERNMENTS AND INDUSTRY IN FISH PRODUCT DEVELOPMENT

At present, product development is being carried out mainly by industries or on their behalf by governmental research institutes with the profit motive in mind. This, however, does very little to alleviate the protein deficiency of low income or underprivileged populations. If fishery resources in the future are to be used effectively to help combat starvation and to meet the protein requirements of low-income groups, product development must be expanded to include the creation of products for which there is at present no profit incentive. This must include the utilization of large stocks of those species which are either presently not attractive or economic for the food fish market or the food processing industry. This can only be done with the assistance of governments and national and international organizations.

Provision of fish to low-income population groups is not a very interesting commercial venture, particularly in the introductory stages. Therefore, the rate of progress in this field will depend largely on the effort made by governments. The use of fish as a food in the fight against malnutrition and starvation can be considered as a public health and social responsibility. Government assistance should, therefore, be available for the technological development of suitable low-cost products and for the organization of distribution chains.

In the research field, however, more widespread government and international assistance is called for. Research in the technology of fish utilization and in the associated engineering problems is subsidized by governments of most of the nations having large and modern fishing fleets. International organizations contribute to these developments and help both governments and industry, particularly those of developing countries, by providing expert assistance, research and pilot facilities, by facilitating training at all levels and by collecting and disseminating scientific, technological and economic information in the fields of processing, distribution, marketing, product standards and hygiene.

The development of fish sausage and tuna ham in Japan, which started in 1950, is a good example of industry and government co-operation. These products were developed on a nation-wide basis to replace meat products which were then in short supply but in increasing demand because of the improved purchasing power of the consumer. Collaboration by governmental and industrial research solved the technical and quality problems, and the industry promoted these products with such success that production rose from 2,000 tons in 1954 to 176,000 tons in 1966 (FAO, 1967b), thereby substantially increasing the supplies of animal protein available to the average consumer.

The Government of the U.S.S.R. also places great emphasis on fish as a valuable source of dietary protein, fat, vitamins and minerals. Product development is carried out on a large scale for the purpose of providing increased food supplies for the population. Over 5 million tons of fish are produced annually (FAO, 1967a), most of which are used directly for human consumption and the raw material for fish meal comes chiefly from waste from filleting and canning operations. The U.S.S.R. was also the first country to tackle the apparently almost insurmountable problem of krill harvesting and utilization. In two expeditions, basic methods for fishing and processing krill were successfully developed.

PRODUCTS OF SPECIAL IMPORTANCE IN UTILIZING POTENTIAL FISHERY RESOURCES

It is well recognized that the world protein problem is extremely serious. For lack of sufficient protein and calories, over 300 million children suffer grossly retarded physical growth and development, and for many of these mental development, learning and behaviour may be impaired as well. Protein-calorie deficiencies also directly affect the health and economic productivity of adult populations. Such nutritional deficits, damaging both present and future generations, are built-in handicaps which must be corrected.

In this connection, fish protein concentrate (FPC), a product which is a suitable supplement for low-protein cereal diets, needs particular attention. FPC, in addition

to its high nutritive value, has the advantage of having a long shelf-life, can be easily transported and packed in such a way that spoilage and insect infestation is prevented. It can also be processed at a relatively low cost. Large quantities of fish can be processed in a short time and species of high nutritive value, but not in great demand on the fresh-fish market or particularly suitable for processing into conventional products, can be used for its preparation.

The development of fish protein concentrates, originally called fish flour, has been undertaken on a systematic basis from about 1954. At that time a substitute for dried skim milk was necessary and it was thought that this product could readily be used.

The processes presently used for preparing fish protein concentrate may be grouped into two main categories: the one-stage process and the two-stage process. In the former, the final product is manufactured directly from raw material which is dehydrated and defatted by means of solvents. The final product is a completely or partly deodorized dry powder with a low fat content. In the two-stage process, the first stage is to produce a dried ground product similar in composition to ordinary fish meal. Fresh fish suitable for human consumption must be used as raw material and, in processing, the sanitary regulations required for food-processing plants must be applied. The second stage is a solvent extraction of the dried ground product. The final product is also a dry powder with low fat content and can be completely or partly deodorized.

Although satisfactory processes are now available, it was not possible to find a ready market for FPC, so its production and use on a commercial scale are handicapped. Protein concentrates are protein supplements of high biological value but should not be considered foods in themselves. In themselves they are not very attractive to the consumer and should be incorporated in foods or added to home-made dishes. An appreciable amount of work in testing their acceptability is still needed, and ways of marketing them successfully must be determined. In developing FPC fortified foods, nutritional needs are met and the new products must be acceptable and even attractive to the consumer. There is evidence from past experience that free distribution of FPC does not necessarily encourage its use on a commercial scale.

Among the various FPC products presently available, the most intensively investigated is without doubt that developed at the College Park Laboratory of the U.S. Bureau of Commercial Fisheries. The Marine Protein Resource Development Committee of the U.S. National Academy of Sciences has stated in a report that this product is wholesome and safe for human consumption, that it is highly nutritious and blends well as an additive to many types of food normally used, that it can be produced at a reasonably low cost and that it is suitable for commercial production, distribution and use in human nutrition.

Based on the exceptionally careful development work undertaken at the above-mentioned laboratory, the U.S. Food and Drug Administration recently decided that a wholesome nutritious product suitable for human consumption could be prepared from whole hake. Preparation has now been made by the U.S. Bureau of Commercial Fisheries for the construction of a plant to produce fish protein concentrate, on a pilot scale, from whole hake.

The ECOSOC Advisory Committee on the Application of Science and Technology to Development and a panel of experts of this Committee have investigated the production and use of FPC in the frame of a comprehensive study on "Increasing the production and use of edible protein". In its report, dated 25th May 1967, the Committee emphasized the importance of FPC as a source of high-quality protein and made a specific proposal supporting the production and marketing of FPC acceptable for human consumption in developing countries with substantial marine resources. In this proposal the Committee concluded:

> To supplement the bilateral funds projected for work along these lines, it is estimated that U.S. $500,000 per annum for support of United Nations' agency programmes should be made available for the first five years, and U.S. $1 million per annum for the second five years for continued research and development, including market research aimed at increasing human consumption of FPC. Based on estimates of costs per annum for facilities likely to be required, at least U.S. $5 million from international sources may be needed over the forthcoming five years for processing plant construction in developing countries, and at least twice this sum in the subsequent five years. If acceptable food products containing FPC are promoted and consumed, ample private capital may be expected to become available to furnish the FPC needed.

To sum up the present status of FPC development, it seems probable that a concerted effort can overcome acceptability problems and other obstacles hampering the promotion of fish protein concentrates and that this will lead to the establishment of a commercial market for these products.

As mentioned above, the full utilization of fishery resources to meet man's future protein needs must include, to a very large extent, the use of fish species less acceptable or unsuitable in their natural state. To be utilized they must be turned into acceptable products. In general these will be products in which the flesh is used in minced, comminuted, powdered, hydrolized or fermented form. They will include such products as fish sausage, fish cake, fish paste, fish protein concentrate, fish extracts, fish sauce, etc. Some of these products are already traditional foods in particular regions and could be introduced elsewhere. They could also be improved and possibly manufactured from additional species which are in larger supply or more available in other areas. The traditional manufacturing methods could be adapted to industrial processing and extended to produce a wider range of products. As an example, the fermentation process might be used in the preparation of FPC products or in a milk replacer for calf feeding.

Whilst the need to utilize the fish resources to alleviate the world protein shortage is of first importance, further thought could also be given to the better use of fish oils in human food and to the use of fish as a source of vitamins, minerals and essential trace elements.

QUALITY REQUIREMENTS IN HARVESTING FISH AND PROCESSING AT SEA

The improvement of quality is an essential part of product development because it reduces wastage and leads to better utilization of fishery resources. Quality problems are mainly caused by the particular nature and variability of the raw material due to the influences of environment,

feed and season. In addition, biochemical reactions, which are influenced by the physiological condition of the fish at the time of catch, take place in the fish flesh immediately after death. These reactions are also affected by the ambient temperature to which fish are exposed on deck, by the handling techniques prior to freezing and by the freezing method itself (Jones, 1967).

A clear understanding of the effect of each factor on product quality and of their interrelation is required to adjust the handling and processing techniques on board the vessels. The sea-going fish freezing industry found that the use of raw material with any sign of bacterial deterioration could easily be avoided by applying known techniques. Experience, however, showed that freezing the freshest quality fish does not necessarily ensure that products of acceptable eating quality reach the consumer's table, even under optimum storage conditions.

Until recently the rapid technical development of freezing fish at sea, with its simultaneous application in all the climatic regions of the world, outstripped the ability of the few technologists who were able to work in adequately equipped laboratories or fishing vessels, to satisfy the industry's growing need for technical information. However, as contributions to this Conference show, technological research has, in the last few years, substantially increased our knowledge concerning the factors which influence appearance, texture and flavour of sea-frozen products. The results of this research clearly indicate that the handling and processing practices applied during the time between the catching of the fish and its freezing have a decided influence on the eating quality of the frozen product. It was found that one of the essential requirements is that fish to be frozen must be cooled down immediately after being caught, since the fiesh is susceptible to breakdown effects when *rigor mortis* develops at high temperature. *Rigor mortis* can develop in fish within a few hours, depending on the species, temperature, condition and other factors. Fish from cold water, even those which live in colder depths of tropical oceans, are more susceptible to temperature damage during *rigor mortis* than those living in the warm surface waters of the tropics (Jones, 1967).

In the light of these findings, provision has recently been made on newly-constructed freezer vessels for cooling fish immediately after they are removed from the net. In the Soviet Union, cooling tanks, through which all fish pass before being frozen, are now being installed on 3,000-ton freezer trawlers of the Mayakowski class.

Research also indicates that delay in filleting may result in improved eating quality of fillets frozen at sea. This, however, may involve the necessity of chilled storage before freezing and would perhaps retard fishing operations (Jones, 1965). The relationship between the time when fish is frozen and the development of *rigor mortis* needs due attention in processing management on the vessel. Differences have been observed between the freezing of whole fish and the freezing of fillets.

It appears that provision should also be made on board freezing vessels for bleeding fish thoroughly before freezing (Jones, 1967).

In freezing fatty fish at sea, the prevention of rancidity may become a problem when longer storage of the product is required.

If good quality frozen fish is to be ensured, the various fish species must be processed in their best condition. While conventional fishing vessels land fish of any physiological condition, and leave the selection and disposal of the raw material to the processing industry, on freezer trawlers and factory ships, it is necessary to make an immediate decision as to the disposal of the fish so that the freezing of raw material which would result in tough or mushy products can be avoided. If the vessel can only preserve fish by freezing, change of fishing ground may be necessary in some circumstances (Jones, 1967).

An important advantage of freezing fish at sea is that it offers the possibility of preserving raw material in its best condition for reprocessing. More information on the economics of freezing raw material to be used by the fish processing industry is needed.

Many countries have established large fleets of fishing vessels and others are increasing their fish-freezing fleets. However, it is evident that the mere production of frozen fish is not sufficient to ensure consumption; marketing and promotion are also necessary and should be included in development programmes. The application of freezing techniques can be considered successful only if the industry, in particular the sea-going freezer industry, can satisfy the quality requirements of the consumer. This depends to a great extent on the management of the freezer ships, which are novel technical units designed for the dual purpose of harvesting the raw material and processing it at sea. Fishermen must, therefore, recognize the technological practices that have to be observed in order to produce final products which will be acceptable to the consumer. Technologists responsible for planning the freezing of fish at sea must integrate processing requirements with the working conditions on the fishing vessels. Fisherman and processor should realize that treatment aboard the vessel can substantially influence the flavour, appearance and degree of toughness of the final product.

The freezing of fish on the fishing ground has brought about new processing and marketing problems related to the quality of the products as well as to the utilization of new fish species. Quality research and marketing research are, therefore, of great importance to the freezing of fish at sea and the results of investigations in both fields should assist and guide those who have responsibility in this industry. There should be a new approach to quality control which should encourage better processing rather than control the end product. In addition, a closer relation between processing and marketing should be established in order to provide technologists with information on consumer demand and reaction to quality and types of product.

SUMMARY

Recent technical advances enabled the sea-going fish freezing industry to play a leading role in the exploitation of fishery resources. In many countries marketing all frozen fish suitable for immediate consumption is, however, a problem facing this industry to a growing extent and it appears that the eating quality of the frozen products is one of the key problems in this connection.

The freezing of raw material for processing industries, the utilization of new fish species and product development in order to compete with other branches of the food industry will need increased attention. The initiative of the industry may solve most of these problems. Measures on a large scale will, however, be required on the part of governments and international organizations to achieve a full utilization of future fish supplies for direct human consumption.

The FAO Department of Fisheries intends to give further stimulus to the promotion of more widespread utilization of fishery resources through its expanding efforts towards the improvement of fish preservation, processing and marketing. In this connection, the Committee on Fisheries at its Second Session, held in April 1967 in Rome, suggested that a panel of experts consider the best ways and means for the wider utilization of fishery resources. The panel may include in its programme items such as the nature of technological and economic studies which should be undertaken, research developments and their practical applications, product development, consumer requirements and acceptability of fish products or protein supplements which can be made from a given raw material, the development of fish processing industries in specific countries and codes of practice.

References

FAO 1962 *Fisheries Report*, No. 1.

FAO 1967a *Yb. Fish. Statist.*, **22**, 406.

FAO 1967b *Ibid.*, **23**, 566.

JONES, N R 1965 Freezing fillets at sea. In *The Handling and Care of Fish at Sea*, supplement to *Fishg News*, 13th August, and *Fishg News int.*, July–September, pp. 40–46.

JONES, N R 1967 Fish as raw material for freezing; factors influencing the quality of products frozen at sea. FAO Technical Conference on the Freezing and Irradiation of Fish, 4th–8th September, Madrid.

UN/ECOSOC 1967 Report of the Advisory Committee on the Application of Science and Technology to Development, 25th May 1967.

New Product Development A Conceptual Approach

by J. C. O'Sullivan

New product development—a conceptual approach

The author examines the effects of new product development in the future expansion of the fishing industry in competition with other industries and outlines an approach to the problem of determining why new fishery products should be introduced, at what rate, when and by whom.

There is an approach to the process of new product development in fisheries that is basically sound and, while any approach must be tailored to meet the unique characteristics of a particular fishing industry, the author endeavours to identify a set of principles which will make this tailoring most effective.

In dealing with the function of government agencies in new product development, an outline is given of the approach in Ireland and of some of the product development work carried out by the Sea Fisheries Board with the fishing industry in recent years. The need to establish clear-cut objectives and the importance to the technologist of identifying the needs of the consumer are discussed.

La mise au point de produits nouveaux—une approche de principe

L'auteur examine les incidences de la mise au point de produits nouveaux sur l'expansion future de l'industrie de la pêche opposée aux autres industries et ébauche une solution au problème consistant à déterminer pourquoi il convient d'adopter des produits de la pêches nouveaux, à quel rythme et à quel moment il convient de la faire et qui doit s'en charger.

Il existe une approche fondamentale et rationnelle au processus de mise au point de produits de la pêche nouveaux. Encore que toute approche doive être adaptée aux caractéristiques spécifiques d'un secteur particulier de l'industrie de la pêche, l'auteur s'efforce d'identifier un ensemble de principes apte à porter au maximum l'efficacité d'une telle adaptation.

Pour ce qui concerne l'intervention des services gouvernementaux lors de la mise au point des produits nouveaux, la communication expose dans leurs grandes lignes les solutions adoptées en Irlande ainsi que certains travaux effectués dans ce domaine au cours des dernières années par le "Sea Fisheries Board" en liaison avec l'industrie de la pêche. La nécessité de déterminer les objectifs avec précision et l'importance que revêt pour le technicien l'identification des besoins du consommateur sont examinées.

Preparación de productos nuevos—enfoque conceptual

El autor examina los efectos de la preparación de productos nuevos en la expansión futura de la industria pesquera en competencia con otras industrias y menciona una manera de estudiar el problema de determinar por qué deben prepararse nuevos productos pesqueros, a qué velocidad, cuándo y por quién.

Existe una manera de estudiar la preparación de productos pesqueros nuevos que es fundamentalmente exacta y mientras cualquier estudio tiene que ajustarse a las características de una industria pesquera determinada, el autor trata de identificar un grupo de principios que facilitará tal ajuste.

Al ocuparse de la función de los organismos gubernamentales en la preparación de productos nuevos el autor menciona cómo se realiza en Irlanda y algunos de los estudios de preparación de productos nuevos realizados en los últimos años por la Junta de Pesquerías Marítimas y la industria pesquera. Examina la necesidad de establecer finalidades concretas y la importancia que reviste para el tecnólogo la identificación de lo que necesita el consumidor.

IN the United States the proportion of new products that fail to make the grade is in the neighbourhood of 80 per cent (Bursk, 1962).

In the United Kingdom the number of new products that succeed is one out of every four that reach the production stage (Thorncroft, 1967).

Two simple statements of fact—but to any of us who are engaged in product development they spell out a fantastic waste of time and money, they warn us of the responsibilities of product development, and highlight for us the need for painstaking organized research into new ideas.

The title which I have given to this paper may seem hackneyed to many of the distinguished technologists attending this Conference, but it is deliberately chosen in that I do not intend to deal with the many technical problems which we encounter in the development of new fishery products—indeed, there are very many technologists far more able than I am to treat those problems. Rather do I intend to deal with concepts and motivations and with how we can improve the probability of developing a product that achieves that one in four label of success. There are many present who will not agree with certain of the views expressed in this paper but, if it serves to stimulate some new thinking on product development, and on how we can increase the share of fishery products in the highly competitive food market, then it will have been worth presenting.

THE CONSUMER IS THE KEY

The fishing industry in Ireland is a small one—small by international standards but growing annually in the contribution which it makes to the national economy. Indeed, this economic growth is the "*raison d'être*" of the industry in Ireland. Many factors can be said to contribute to this growth, but the predominant one is a recognition of the consumer and of his needs, backed by an all-out effort to encourage the production and marketing sections of the industry to satisfy those needs. The fishing industry is defined not as an integral industry in itself but as part of a wide and competitive food industry and, in fact, if one extends the imagination a little further and examines the reasons as to why people go out to dine on our seafood products we may well define ourselves as very often competing even with a whole leisure industry.

At BIM (Bord Iascaigh Mhara: Irish Sea Fisheries Board), which is the Development Corporation for the sea fishing industry in Ireland, this is the sort of thinking that prevails. Whether we are considering the financing of fishing vessels, the marketing of fishery products, the education of skippers and of their crews, the development of new products—it is preceptual that these varied and apparently unrelated activities must all be directed towards economic growth that can be measured in the market place; and whether or not we have anything to measure depends on the consumer and on how successful

we are in meeting his requirements. There is no one market for fishery products and in this context the consumer must be defined as any user or potential user of any product based on the raw material fish; and when we consider that in this paper the writer deals only with fishery products for human consumption, we are made even more aware of the magnitude of the task confronting us in new product development.

WHAT'S NEW?

There are probably as many definitions of a new product as there are people engaged in new product development.

The food technologist, in thinking about new products, more often than not scans food horizons and dreams of the achievements and of the revolutionary developments of an Edison, a Siemens or a Birdseye. Most of the time it escapes us that the invention of Birdseye was just one of some 140 freezer developments patented in the United States alone in that particular decade. To the simple question: "What did Birdseye invent?" many may answer "The plate freezer". But one can also answer "The frozen food industry".

While there may have been many inventors of the freezer, it was Birdseye who recognized its significance as a link in the creation of a frozen food industry. He it was who asked such questions as "What are the major economic opportunities which this development opens up?" and "What are the consumer satisfactions which it can fulfil?", and went on to build a major industry.

The consumer very often does not notice that products are new and certainly, when making his purchase, does not take into account the long, painstaking and expensive process that brought an idea into product reality. At best a new product is something he never bought before, even though he may have bought a very similar product in a different type pack, with units of different size, at a different price, or with slightly more or less flavouring or colour additive.

To the manufacturer, as a general rule, whatever the marketer considers a new product is a new product—even if it is simply a change in styling, an added line to an existing range or even the replacement of a soft-pack by a new flip-top pack (backed by a spectacular advertising campaign).

Products can, in fact, be new—frozen foods, motor cars, TV dinners, A.F.D. foods, "miracle" fibres—but are these any more new than the addition of a colour ingredient to an otherwise unchanged toilet tissue? Only the consumer will judge; in fact, only the consumer will define it as a new product at all rather than "a great new idea" which has become just another Cinderella—an 80 percenter.

A product, be it new or old, must be defined broadly in terms of a whole group of satellite attributes which produce distinct consumer satisfactions—in fact, one might define it as a cluster of customer value satisfactions. One of the few things we know for sure about consumers is that they are constantly changing in ways that are extremely important to the technologist. Success is achieved through anticipating and acting on these changes and through doing it at the right time and in the right way. We have always lived in a world of change, but what makes present-day changes different from changes that came before is that they are coming at us more rapidly; and the customer does not stand still while we take our time in adding those extra refinements to our brainchild.

WHY NEW PRODUCTS?

Long lists could be compiled of the reasons for developing new products and of the important contribution which new products make to industrial growth.

Business history indicates that growth industries have been heavily new-product oriented and this, for the United States, is borne out in fig 1 (Berg and Schuchman, 1963) which compares research and development (R & D) expenditures, which are a partial measure of new product effort, with the growth rates of selected industries.

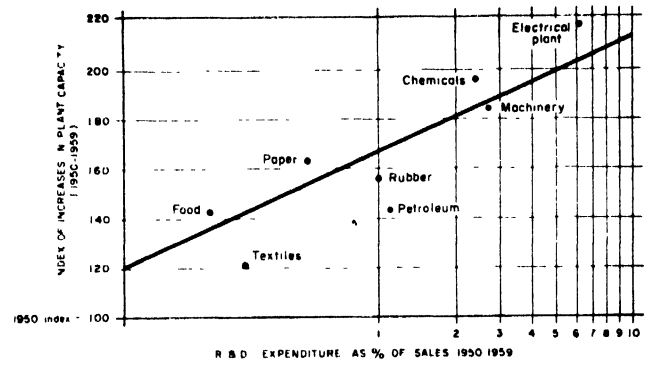


Fig 1. Increases in plant capacities related to R & D expenditure

As can be seen, those industries spending the most for new product development have, in the main, experienced the greatest growth. Furthermore, in the United States, in an interview (Berg and Schuchman, 1963) of companies to determine the effects of new products in industrial growth, all companies reported that an average of 43 per cent of sales came from products introduced during the previous 10 years and forecast that 56 per cent of sales 10 years hence would come from products not yet developed. Separating the industrial companies from the manufacturers of consumer products, the consumer companies predicted that 57 per cent of their sales 10 years hence would come from products to be developed within that period. These latter figures are very relevant from the point of view of the development of seafood products.

New product development has been accelerated by post-war changes at alarming speed. Markets have been and are shifting rapidly—people are moving from city to suburb and from suburb to outer suburb, making of the areas between towns spreading complexes of multi-economic-level consumers. More people have more money and more varied appetites and their tastes are offering many profitable markets within markets. Technological advances have, however, made it easier to produce what consumers want at a faster rate than products can be sold and in the competition that arises from this tightening market new products have been the most effective weapons.

One of the greatest myths regarding increased demand that must be exploded is the population myth—the belief that increased consumption of a product is assured by an

expanding and more affluent society. And yet, how many projections of consumption do we see in the fishing industry which are based on precisely this hypothesis. In fact, it seems to be a theory that is dear to the heart of many responsible people in the fishing industry who are to be content with a policy, which is at best neutral if not negative, that the fishing industry should hold its own; and there is no surer way to slide on the downward path. Consumption of fish arises only out of the satisfaction of a number of consumer needs by a range of fishery products—be it prepacked fresh fish, conventional fresh fillet, frozen fillet, a fish tasty or a herring on a stick. But who is to say—and here I wear my consumer's rather than my technologist's hat—that by the time the population has grown in line with projected production, I will want to eat fish at all? This preoccupation with population rather than consumer satisfactions very nicely takes the edge off the apprehensions everybody in the industry understandably feels about the future. In fact, it can very often breed complacency and certainly relieves the industry of the responsibility of having to think hard or imaginatively.

In marketing-oriented economies, products, by and large, have a life cycle. Most of us are familiar with the curve but since we cannot tie down the dimension on the time axis we begin to doubt the validity of the assumption that product life cycles do conform to a set pattern. The writer, in 1964, plotted life cycle curves for a random sample of consumer products and a typical curve is reproduced in fig 2. The profit margins from the products

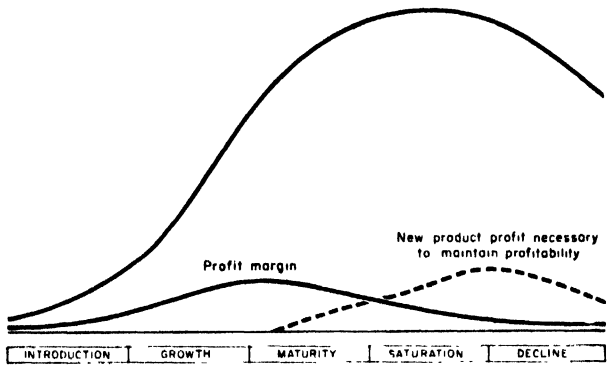


Fig 2. Product life cycle curve

have also been plotted on the curve and the fact that sales and profit curves are not in phase is most significant. The broken line in fig 2 indicates that profit margin which must come from new products if the overall level of profitability is to be maintained.

People can quote products which have defied the challenges of time and show few signs of growing tired. Aspirin is such a product which must be almost unique in an industry which is noted for its high rate of innovation. Products of this type, however, are very rare indeed and sometime in the future someone will plot the product life cycle of aspirin and try to figure out why it covered such a long life span—because no product lasts forever. Sooner or later every product is pre-empted by another or else degenerates into profitless price competition.

Survival of an industry or business in a marketing economy depends on the introduction of new products and the re-vamping of old ones. The incentives for the introduction of new products do not always stem, however, from a reading of life cycle and profit margin curves (which reading, incidentally, would be interesting if someone were to obtain the data and plot the curve for fish fingers). Those incentives in an industry or within a company can be many but generally include the following:

(1) to recognize an un-met need;
(2) to use excess production capacity;
(3) to utilize waste materials;
(4) to achieve more added value to materials;
(5) to counter what competitive industries or companies are doing;
(6) to resolve problems of instability of supplies of raw materials;
(7) to make a product obsolete;
(8) to respond to changes in distribution channels and outlets;
(9) to meet suggestions from the market.

One could go on and on but two additional considerations must be added on which the fishing industry seems to place particular importance. These are:

(10) to achieve greater exploitation of under-utilized fish resources;
(11) to feed under-nourished populations in developing countries.

Any one of these two reasons can be a good and a sound one, but sometimes, in our enthusiasm to achieve greater exploitation of fishery resources or to provide a protein diet for starving millions, we forget that a product is not a product until the consumer establishes it as such and that it must carry with it consumer satisfactions; and as protein-starved people subconsciously respond to their needs and satisfy them, they may very well not define their needs as protein.

If a new development is to become a product and not remain a R & D breakthrough or an academic achievement in the field of technology, there must be created a desire among consumers to use it. At this stage, one must not produce products but must concentrate on the production of consumer satisfactions. The entire fishing industry including its R & D sector, must be viewed as a consumer-creating and consumer-satisfying organism—even if the consumers we have in mind are protein starved.

FINDING A WINNER

What people in the fishing industry think they know about the consumer and the market is as likely to be wrong as to be right. It is only by asking the consumer, observing him and trying harder and harder to understand his behaviour that we in the industry can find out who he is, what he wants, how he uses what he purchases, what he expects from it and what are his values (and he has values and he has preferences even if he has not enough animal protein in his diet). The consumer rarely buys what we develop for him and think we sell him. The industry sells a fishery product—the consumer buys satisfactions. Our product is not in itself the satisfaction but the vehicle for consumer satisfactions; this we must always keep in mind. Because the consumer buys satisfactions, our fishery products compete intensively with

goods and services that are totally different, seem to serve different functions, are made, distributed and sold differently but are alternative means for the consumer to obtain those satisfactions which he desires.

Unless there is a constant and careful audit of consumers, potential consumers and society generally, there can be no basis for assessing the value satisfactions that new products will offer. The way to develop successful products is to know what will attract the consumer; and an essential start is to ask oneself to what kind of society will our consumers belong in, say, two, five, ten years time, when our product will be going through its life cycle. Those, however, are the questions that are normally purposely ignored by the product developer because they are so patently hard to answer; and his mind, which likes neat and tidy analytical results, reverts to his new formula or to that sample of product newly developed and discusses with his colleagues all the reasons why it must be a success.

In developing a new product or in doing a re-vamping job on an old one (or in seeking further outlets for under-utilized species) all the standard questions should, of course, be asked: "Who is the consumer?" "How does he buy?" "What are his needs?" "Which of his needs does the product we have in mind satisfy?" "Under what circumstances—age, family structure, etc., are those needs most important to the consumer?" "Where is he?" "What are our direct and indirect competitors?" "What are they doing and what are they about to do in the future?" These are all the questions that are usually asked; but what of the ones, often the most relevant in the case of fishery products—"Who is the non-consumer and why does he not buy?" "Will the product we have in mind fulfil the satisfaction areas of real importance—those which we now serve and those which we should be serving?" "Are we in the food business or, taking into account current fashions and dietary habits, should we, in fact, be seeking a share of the successful anti-food market?"

There is a basic approach to the process of new product development that is sound for most companies in most industries and, while in the fishing industry any pattern of approach for a new product programme must be tailored to meet the unique characteristics of the particular fishing industry or country concerned, this tailoring can be most effective when working from an established set of principles which I will endeavour to identify.

There are six fairly clear stages in product evolution (although the labels which can be tagged to these stages can be many and varied) and they are as follows:

Exploration
Screening
Commercial analysis
Product development
Product testing
Commercial exploitation

These needs break down as follows:

Exploration: this is a search for consumer needs and for product ideas to provide consumer satisfactions.

Screening: an analysis to find which ideas are relevant and worth further investigation.

Commercial analysis: the expansion of the idea through creative analysis into a concrete business recommendation acceptable to a company. The recommendation should cover product features, general commercial feasibility and should incorporate a development programme (and budget).

Product development: turning the idea-on-paper into a product-in-hand capable of production and demonstration.

Product testing: the marketing and commercial experiments necessary to verify earlier commercial judgments.

Commercial exploitation: launching the product in production and market committing the reputation and resources of a company.

A "decay curve" for product ideas can be plotted for various industries and companies and fig 3 is the decay curve plotted for a leading Irish company which carries out an extensive product development programme for consumer food products (including fish products).

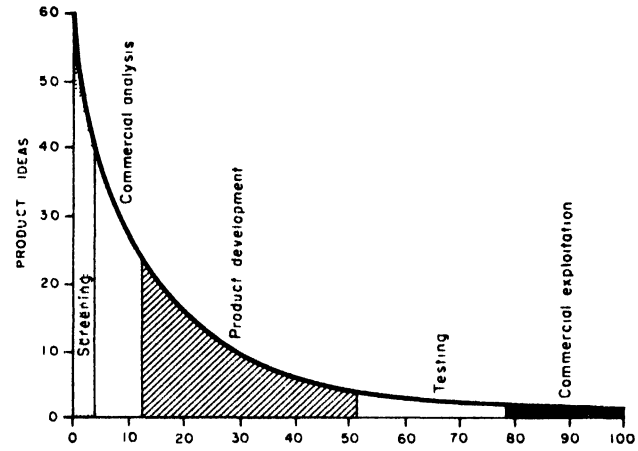


Fig 3. Decay curve for product ideas

Although the rate of rejection varies between industries and, indeed, between companies, the general shape of the curve is typical and it will be noted that it takes some 60 new ideas to yield one successful new product.

Of greater interest still may be fig 4 which shows the relationship between expenditures of time and money during the various stages in product evaluation. It will be noted that each stage is progressively more expensive and time-consuming (the costs do not include capital costs). Some 40 per cent of cumulative time spent at the product development stage accounted for only some 20 per cent rejection of original ideas as against some 37 per cent rejection for only 9 per cent of total time spent on screening and commercial analysis.

It is estimated (Booz, Allen & Hamilton, Inc.) that of total new product expenses almost 80 per cent goes to unsuccessful products and that 70 per cent of the "wasted" money is at the product development stage. On this estimate, about seven out of eight development scientists and engineers may be said to be working on projects that will not be justified in terms of commercial usefulness (and the above figures do not include basic research).

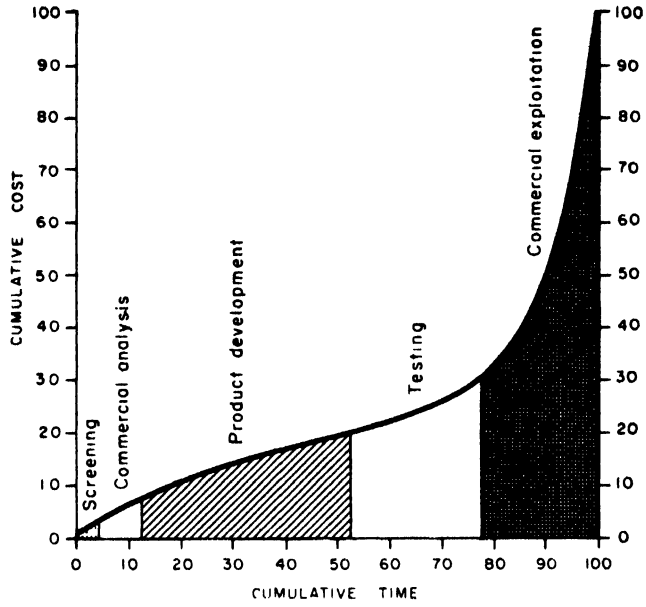


Fig 4. Cost to time accumulation in product evolution

In examining the process of new product evaluation, the conclusion is reached that heavy attention should be focused on the first three stages—the "idea" or "concept" stages. Most products fail because the idea or the timing was wrong and not because the knowledge or the technology necessary for the development of the product was lacking. A high percentage of development work takes place, after all, within a technology which is largely understood at the outset—but all too often ideas start with the laboratory rather than with the question: "What should be developed?" There are plenty of problems to be solved in the world and the secret of success for the fishing industry will be to work on the useful ones; and, while describing the need does not satisfy it, nevertheless, careful and accurate description of the need gives a realistic specification for economic results.

WHAT IS PRODUCT DEVELOPMENT?

From the point of view of the fishing industry, most new product development work is carried out by government agencies or by fish processing companies. To the writer's knowledge, the idea of having a new product development programme handled by marketing consultants is one that has not yet been generally accepted in the industry even though it is a system in which the greatest levels of objectivity and dispassionate evaluation can be maintained. Too often, however, from the writer's experience in the fishing industry, product development programmes emerge as a rather hefty investment in the laboratory director's ego and too seldom are the basic questions asked regarding consumer needs. Even when we do go through the respectable ritual of trying to find out what are the consumer's needs, in the end we are more interested in how these facts can be used to justify our pet project than in how they can be used to dictate what the product should be in the first place, how it can be designed, and even how it can be delivered so that the consumer will prefer it over all other demands on his money.

In the case of a fish processing company, the necessary tools normally exist within the company for a rational new product approach even though, very often through lack of a proper organizational approach, the company's strengths are not co-ordinated. It is the exception rather than the rule for a new product programme to be organized as suggested by the writer above, and almost invariably product development programmes are entirely "laboratory orientated", a system in which the scientist is the only figure. The scientists, however, who occupy those key positions in their companies very often break the cardinal rules of their own scientific method, (i) being aware of and defining the problems, and (ii) developing and testing hypotheses to solve them. They are seriously scientific about matters within the four walls of their laboratories, but they are very often the first to consider that problems relating to the consumer are unrelated to the affairs of the technologist.

There can be many cases of spectacular and revolutionary discoveries which are the inventions of individuals working, in a sense, "outside" of their markets. In the case of "miracle" fibres, for instance, it is very difficult to imagine that any marketing approach could have resulted in the specification for a product that could be woven, moulded, blown, extruded, machined and made into a range of products from ladies' stockings to heavy carpets. But the bulk of new products in the market do not require any great scientific breakthrough or any startling invention. What is required in product development is a new product approach in which all the strengths of an industry (or a company) can be harnessed towards achieving new product success.

While co-ordination can be achieved in companies through the creation of new product departments, how can a government agency tackle this problem successfully? At BIM our approach as a development corporation is to simulate the functions of the industry—marketing, finance, production, research and development, etc. To do this successfully, one must enjoy the confidence of the various sections of the industry and work with them and through them. Product development starts with product ideas and those ideas may come from consumers, R & D people, our marketing division, companies within the industry, companies outside the industry, from a fishing skipper—in fact from anybody. The source is not important and fishing for ideas is by no means confined to technological people. If an idea, however, is to become a product someone must produce and market it and it is very important that a company or group of companies be involved from the very beginning. The companies may not be manufacturers of fish products at the commencement of the project so long as the product idea is within their product policy as they define it; and allocation of our resources—both people and money—does not relate only to the technological development of the product but also to the application of the screening process, the commercial feasibility analysis, market research and test marketing programmes—and ultimately to product launch. It is our belief that if product development is to have a material effect on the growth of our fishing industry, there must be this melting pot into which all experts are brought together.

SOME SPECIFIC CASES

At the outset I stated that I would deal in concepts rather than specifics, but lest I have created any illusion that we in Ireland have successfully avoided the pitfalls I have outlined, let me hasten to assure you that we have our failures as well as our successes in that elusive hunt for the one-in-four winner.

- The special pack kipper products that became a market failure within one year, after an initial favourable market impact that exceeded our best predictions.
- The fish finger manufactured from whiting (*Gadus merlangus*) which marketing people predicted would not sell but which, in a carefully planned test-marketing operation, the consumer rated as being on par with the best cod (*Gadus callarias*) products; and which, after three years, is gaining an increasing market share.
- The wine-flavoured "fish tasty" which everybody concerned with the product at the ideas stage considered a sure winner but which the consumer rejected out of hand at the test marketing stage.
- A range of pre-cooked, portion controlled, fillet products which failed due to ineffective marketing effort—or, perhaps, due to the fact that they were ahead of their time for the Irish consumer. Only the consumer really knows! But now, some few years later, the same products are being very successfully marketed by another company.
- A fish sauce project which has come through the ideas screening process and the qualitative and quantitative evaluation stages (even though the product has not yet been developed) and which, if successful, may result in the successful marketing of certain varieties of fish.
- New methods of presenting wet fish (which very few technologists would be inclined to define as a new product) which will be a new product to very many fish consumers—or, indeed, non-consumers.

In Ireland, research resources—both in terms of money and people—are small and, with our industry at a stage of development where expansion depends on increased exports, we must use every means at our disposal to eliminate the high percentage of "waste" that one normally associates with research projects, so that the necessary market penetration and market share can be achieved using the resources at our disposal. Because of those limited resources, we must try harder than most other countries to define clearly where we should go and what our consumers at home, and in foreign markets, want (or need without consciously wanting it) that we can provide—and most of all, we must ask ourselves again and again where our industry is going and what our business will be in the future.

CONCLUSIONS

The definition of what the fishing industry really is, the projections regarding where it is going and where it will be five, ten years hence—these are the factors which determine the R & D programmes which will play such an important part in its getting there. But if we in the industry do not know or care where it is going then all the top technologists in the world cannot get it there.

In the field of product development a vast amount of knowledge exists and it will be obvious from the papers presented at this Conference that this basic knowledge is being added to at a tremendous rate all over the world. If, then, R & D fails to meet the objectives set for it, to the detriment of the industry, it will more often be because of wrong or faulty concepts than for technical reasons. It is on this basis that R & D programmes should be selected.

The fishing industries of the world will thrive on innovation—on the design and development of new products which will establish a new configuration out of the old known, existing elements and give these elements an entirely new economic dimension. The era of brilliant improvisation by the company manager is past. Innovation, however, is not invention or discovery, although it may require one or the other and sometimes does. Its focus is not on invention but on performance and its essence is conceptual rather than technical or scientific. the characteristic of the innovator is the ability to envisage as a total system what to others are separate elements and to provide the smallest parts missing from this system. His innovation is the conversion of these elements—knowledge, technology, products, markets, consumer demand—into a new and more productive whole.

How can innovation be successfully achieved and, indeed, successfully managed? The J. Walter Thompson Agency, who have been responsible for many very successful product development projects in the United Kingdom, contend that "product development is 90 per cent communication and 10 per cent originality". The fishing industry must begin with the customer and his needs and, working in reverse, must then concern itself with the delivery of customer satisfactions; it must then move a further step backwards to creating the things (the products) through which these satisfactions will in part be achieved. The industry must look upon itself not as producing goods but as winning consumers.

This total will make new demands on the technologist in which, I am sure, he will not be found wanting. The job, if tackled purposefully, responsibly and with knowledge and forethought, will be exciting and stimulating. It offers an intellectual challenge and the unique enjoyment which we will all derive from creating order where, to a large degree, chaos exists.

References

BERG, T L and SCHUCHMAN, A 1963 *Product Strategy and Management*, Holt, Rinehart and Winston Inc.

BOOZ, ALLEN and HAMILTON INC. 1960 *Management of New Products*, Booz, Allen and Hamilton Inc.

BURSK, E C 1962 *Text and Cases in Marketing: A Scientific Approach*, Prentice Hall Inc.

THORNCROFT, A *Financial Times*, June. 1967

New Product Development

by P. F. C. Sale

New product development

Any food company needs new products to maintain its share of the market and to secure more efficient use of plant and resources. New product ideas are often a new twist of an old theme but even with simple ideas it may take years to overcome the many technical problems.

To be successful new product development must be encouraged by top management. In our company the regular meetings to review development progress are attended by the full board.

A typical product development team comprises the product marketing manager, the product development manager and the product cost accountant. By using attitude surveys and consumer tests of trial products, the marketing manager determines what kinds of new products will provide good commercial opportunities. The development manager should possess both imagination and technical knowledge in order to devise the best way of making the new products. The product cost accountant must ensure that the products are commercially viable.

Technical development begins with a literature survey and basic research into raw materials, process methods and packaging materials. Development proceeds from the kitchen stage, where a number of alternatives are considered. Gradually sample batches are scaled up and the choice is narrowed down to the final product. A pilot scale production line is built and the potential problems of full scale production are assessed. A test market is then arranged. If this proves satisfactory a decision is made to launch the new product.

Such new products are always a risk but a risk that must be taken for any company that wishes to progress.

La mise au point de produits nouveaux

Chaque fabricant de produits alimentaires doit faire une place aux produits nouveaux afin de se maintenir sur le marché et d'assurer l'utilisation la plus rationnelle possible des installations et des ressources existantes. Les idées conduisant à la mise au point de produits nouveaux ne constituent fréquemment qu'une nouvelle façon d'envisager un vieux problème; pourtant même les idées les plus simples peuvent poser des problèmes techniques dont la solution demande des années.

L'élaboration de produits nouveaux doit, pour être menée à bonne fin, être encouragée par les instances supérieures de la direction. Dans notre société les réunions régulières consacrées à l'examen des progrès dans ce domaine sont suivies par l'ensemble du comité directeur.

L'équipe-type de mise au point des produits comprend le directeur commercial, le directeur de la fabrication et le chef comptable. Le directeur commercial établit les possibilités de tel ou tel produit nouveau en se fondant sur des enquêtes de motivation et en faisant essayer par des consommateurs les nouveaux produits. Le directeur de la fabrication devrait être doté à la fois d'imagination et de connaissances techniques afin d'être en mesure de déterminer la meilleure manière de fabriquer les produits nouveaux. Le chef comptable doit être à même de s'assurer de la viabilité des nouveaux produits sur le plan commercial.

Du point de vue technique, la mise au point de produits nouveaux commence par l'étude de la littérature et par des recherches fondamentales sur les matières premières, les méthodes et les emballages. En pratique, on part de la cuisine, où différentes possibilités sont envisagées. Le lot d'essai s'élargit peu à peu puis le choix final s'établit par éliminations successives. Une ligne de production à échelle réduite est construite et les problèmes relatifs à l'exploitation industrielle sont examinés. Un marché expérimental est alors constitué; si les résultats sont concluants, la décision est alors prise de lancer le nouveau produit.

Ces produits nouveaux présentent des risques qu'il convient d'affronter si l'on veut progresser.

Preparación de nuevos productos

Todas las empresas dedicadas a la elaboración de alimentos necesitan productos nuevos para mantener su participación en el mercado y para emplear más completamente las instalaciones y los recursos. Con frecuencia, las ideas relativas a un producto nuevo son solamente modificaciones de un tema viejo, pero aun en el caso de las ideas más sencillas pueden transcurrir años antes de que se solucionen los muchos problemas técnicos.

Para que un producto nuevo tenga éxito ha de ser objeto de estudio y estímulo por los directores más altos. En nuestra compañía la Dirección asiste a las reuniones periódicas en las que se examinan los progresos de la preparación de productos.

Un grupo típico de preparación de productos nuevos lo forman el director de ventas el director de preparación de productos y el contable encargado del examen de los costos del producto. Empleando reconocimientos de aptitudes y pruebas entre los consumidores, el director de ventas determina qué clases de productos nuevos ofrecerán oportunidades comerciales. El director de productos nuevos debería ser una persona de ideas y conocimientos técnicos para encontrar la mejor manera de preparar nuevos productos. El contable encargado de los costos de los productos se asegurará de que éstos son viables comercialmente.

Los progresos técnicos comienzan con un examen de la literatura e investigaciones fundamentales de las materias primas, métodos de elaboración y materiales para empaquetar. La preparación comienza en la cocina, en la que se estudian diversas posibilidades. Gradualmente se incrementan las muestras de ensayo y se reduce la selección hasta llegar al producto final. Se construye una cadena de producción en escala de ensayo y se evalúan los posibles problemas de la producción a plena escala. A continuación se organiza un ensayo de mercados y si éste resulta ser satisfactorio se decide iniciar la preparación del nuevo producto.

Estos nuevos productos representan siempre un riesgo que tiene que correr toda empresa que desee progresar.

WHY do we need new products?

(1) To fill the product gap.

(2) Housewife wants a change—variety of choice.

(3) Sales need new impetus—product revitalization.

(4) Maintenance of sales' position—to face competition.

(5) Diversification of company effort.

(6) Utilization of plant and factory resources.

PRODUCT INCEPTION

Personal ideas

The original idea for a new product can come from one of several sources which may be either inside or outside the organization.

In fact, most of the really successful products are more likely to be either quite familiar foods presented in a new and more convenient form or interesting new variations on themes which become surprisingly familiar if examined closely.

For instance, in 1965 a completely new product, made by putting chunks of filleted cod inside a special batter, was launched. It took years to develop this product which is wrapped in a particularly nice pack—much admired even by the manufacturer's competitors. So everything about the product is new except, oddly enough, the basic idea, which must be at least 100 years old because it is the same as the one on which that great British institution known as fish and chips is also based.

It was comparatively easy for the manufacturers to recognize that there ought to be an opportunity in finding

a new way of combining really good quality fish and the sort of crisp, golden batter produced by any really good fish and chip shop—of which there are thousands in Great Britain. However, getting from this simple idea to the final product was not an easy task. It took over two years to launch the product in which time literally hundreds of permutations of different batters, shapes, sizes and, of course, names, were considered. Despite its deceptively simple appearance, it was an extremely difficult product to mass produce economically, and required much ingenuity and sheer inventive ability from technical and production staffs in solving what sometimes looked like an apparently endless set of problems. The name, finally selected from 200 possibilities, was thought to convey an extremely accurate impression of the product even to people who had never seen or heard of it before.

Ideas on new products should always be encouraged within any company. The idea is the seed which requires planting and careful husbandry, if it is to flourish. This is largely determined by an attitude of mind in the senior management team without which no real advance can be made in the field of new product development. If I may be permitted here to give my own company's view on this important point, my Chairman together with his complete Board attend all development meetings which take place regularly at six-weekly intervals.

In other words there must always be a basic new product strategy within which all activity in the area of the Company's undertaking is directed and controlled. In many companies, the need for long-term product planning is neglected and overlooked and it should always be remembered that new products take a long time to develop, and it is not just a case of pressing a button.

Of the many ideas tried and proposed it is likely that very few will have a chance of real success, but this should not be a discouragement, but rather the opposite—it should be the spur to even wider thought and application.

Product intelligence

(1) Establishment of the need for the product by basic market research, to answer the questions "Is there a real need for the product?" and "What is the product intended for?"
(2) Market research and analysis.
(3) Outside survey teams—group discussions.
(4) Internal sales/customer contact.
(5) Direct customer approach.

Establishment of product characteristics in answer to the questions "What must the product be like?" and "What must the product do to satisfy the potential customer?"

The marketing and sales view.

(1) Changing buying habits.
(2) Convenience meals.

For example, the latter category of convenience foods now accounts for about 25 per cent of the £5,500 (U.S. $13,200) million spent on food in Britain in a year.

The technical development view.

(1) Basic considerations.
(2) Processing.
(3) Packaging.

THE PRODUCT DEVELOPMENT TEAM

First and foremost it must be realized that any development must be a team effort and in any product group there must be the following people who are responsible.

A product marketing manager

The job of a marketing man is to use the skills of this relatively new profession to study the habits, the attitudes and the aspirations of the people of Britain in order to try and recognize good commercial opportunities for the introduction of new products or the improvement of existing ones.

It is also part of his job to encourage the many specialists now involved, including scientists and technicians, to develop and produce products which will meet these requirements, and then, if it is decided to risk the large investment which has to be put behind such ideas these days if they are to stand any chance of success, to use his public relations and advertising skills in an effort to persuade his potential customers to give the new product a try.

And since his potential customers are nearly always busy housewives with plenty of other things on their minds, he tries to communicate with them through many different media including packaging, shop display, newspapers and magazines, posters, television and all the other methods available to him if he thinks they are worth using.

The product development manager

Under whose responsibility the process of product development in all its technical aspects rests. Ideally it is essential that his department maintains its lead by constant research into fundamental studies, so that the results can be applied at the appropriate stage of product formulation and so that full advantage can be taken of published work.

Product development requires, almost above all else, a keen sense of basic food needs and not a little imagination and flair for this type of work. But this alone is not enough; once an idea has been proposed, then all further stages demand a high degree of technical knowledge and competence in the relative field of activity, and be this basic food chemistry, nutrition, processing technology, packaging, marketing, etc., this manager has to ensure that all members of the technical development team operate to full capacity and efficiency and to make a worthwhile contribution to the team's progress. It is getting progressively more difficult for him fully to achieve his company's targets, and any company that really stands to make its mark must of necessity establish and maintain a really first-class team of specialist services and functions for him to deploy to this ultimate objective.

The product accountant

Last but not least in the team is the accountant whose all-embracing responsibility is that of providing the team with the necessary financial data upon which can be

assessed the basic cost of the product. This must of necessity involve:

(1) Raw material costs.
(2) Labour.
(3) Packaging.
(4) Capital outlay.
(5) Distribution and storage.
(6) Overheads.
(7) Advertising and promotion costs, and all the other necessary cost factors which it will be essential to take into account in order to give senior management the information they need to arrive at the feasibility and decision to proceed with the project.

THE DEVELOPMENT PROCESS

Literature search

This is a very necessary first step in order to take full advantage of past experience and published work. This can, very obviously, save considerable time at later stages, particularly where process of a fundamental character has been studied. The literature search should establish as many facts as possible under the following headings:

Basic research in the food product concerned (e.g. meat, fish, cheese, etc.)
Processing data and difficulties
Patents
Stability
Packaging

Basic product concept

At the same time, the technical development team will be acting to establish as many facts as possible:

Raw materials
Sauces
Grades
Types, e.g. cod, haddock, etc.
Microbiological factors
Packaging—reliability and presentation
Handling methods
Test methods
Specifications
Process control methods
Machinery design and line layout
Flavour aspects
Texture, colour and other associated factors governing product acceptability.

Basic product formulation

This is probably the most difficult stage in the whole sequence and requires an expert in home economy methods. Fully-trained kitchen services capable of handling all types of food products are of course essential.

Progressing through kitchen stages: At this stage, fullest use should be made of the specialist technical services offered by the major supply businesses. If one wants to know all about certain raw materials, their characteristics, usage, stability, etc., then the technical expert of the company that specializes in this product should be sought, and close collaboration between the test kitchen and the company's laboratories should be established.

The whole object of this stage is to produce a range of alternatives within the accepted basic concept of the new product and by so doing, to discover any processing snags and to eliminate any products which do not rank sufficiently high in the acceptance tests. The final result of this work, is the production of new products which the product manager feels stand the greatest chance of success, and the drafting of full processing instructions.

Product reliability

Having selected the new product, it is then necessary to determine its reliability. By this we mean whether or not it can be transferred satisfactorily from the kitchen to the manufacturing stage, and its characteristics in storage, handling and ultimate use by the customer. This must involve a series of tests (often long-term, even up to one year if necessary) in order to establish:

(1) Shelf life, particularly changes in texture, rancidity, colour, etc.
(2) Flavour change, to ensure full flavour retention under cold storage conditions.
(3) Weight loss.
(4) Shrinkage.
(5) Conditions of customer usage.

Specifications

Once the product has been accepted through the previous stages, it is then ready for final approval, but before this can be considered, it is necessary for the company quality control staff to be brought into the picture and for specifications to be drafted in respect of:

(1) Any raw materials used.
(2) Any processing methods involved.
(3) Any packaging materials used.
(4) Label design and wording.
(5) Final product control.

Product acceptance

The next stage in the process of the development involves two approaches:

(a) pilot production;
(b) test market procedures;

to establish the overall characteristics of the product and to provide data for the forward planning of full scale production and sales.

Review

After the completion of all of the above, it is then necessary to pull together the whole team and to iron out all problems that have arisen. As a result of this, the product manager is then in a position to offer his ideas and suggestions to senior management for final clearance and product launching. Such a meeting would usually determine such things as target dates, production capacity, availability of raw materials, final costing, schedules and the details of the launching campaign.

It might be thought that once the product had gone through all these stages that all would then be plain sailing. Unfortunately, there are frequently snags that just cannot be foreseen. There is nothing so unpredictable as the housewife, as in spite of detailed market research

there is no guarantee that the product once on the supermarket shelf will sell. It is therefore a necessary final stage in product development for a check to be made on the overall sales effort and results.

Naturally there are almost certain to be complaints of one sort or another and these must be given the very closest attention. Such a regular review by the product manager ensures that any difficulties are tackled and solved speedily and will establish whether the initial product is a success or otherwise. If necessary, he would initiate any modifications which might be necessary to ensure continued sales.

The whole burden of this process is, as you will see, one of close collaboration by a team of experts each contributing to the fullest extent to ensure complete success. It is one of any successful company's main duties to have such teams and to provide them with the fullest facilities to carry out this vital function, and for a company that does not develop new products, it is quite incapable of expansion and growth, and ultimately becomes moribund.

Product information to sales staff

This is a function of the marketing product manager who must keep the sales force fully informed of progress as far as new lines are concerned. There are numerous ways of doing this, and each company will doubtless have its own ideas on the subject. Whatever the method used, the sales force must be given the necessary information and support to give them the necessary chance to complete the final and most important sequence to the ultimate end of any new product—that of selling it.

Product Development and Vacuum Packaging Techniques

by J. Aagaard

Product development and vacuum packaging techniques

Various examples are given on the application of the vacuum packaging technique in the development of new frozen fish products. The products are of the so-called ready-to-cook type, packed in suitable plastic pouches. Vacuum packaging has been found indispensable for all the described products, because it prevents desiccation and development of rancidity of the fish during cold storage. Besides, the vacuum packaging technique may facilitate the manufacture of the products in various ways. For example, herring (*Clupea harengus*) fillets, packed in aluminium trays, are covered with a mixture of breadcrumbs and flavoured butter. The mixture is spread evenly on the surface of the herrings by means of the pressure formed by the vacuum packaging. Another product, marinated herring fillets, is frozen around a stick. The combination of the pressure formed by vacuum packaging and the freezing procedure makes the herring adhere to the stick even after deep-fat frying. In a third product, different kinds of herbs and spices are placed between two fillets. The fillets are then vacuum packed, which makes a close contact between the flavourings and the fish meat. By this contact the flavourings are readily absorbed by the meat, and the "gravad" fish may then be frozen. Finally a description is given of the shape of frozen blocks of fillets, which act as a semi-manufacture for different types of products. The blocks have been shaped with a view to minimizing leakage of the plastic pouches after vacuum packaging of the finished products.

Nouveaux produits et techniques d'emballage sous vide

La communication illustre l'application de la technique de l'emballage sous vide à la mise au point de nouveaux produits de la pêche congelés. Il s'agit de produits du type "prêt à cuire", présentés en sachets de plastique. Pour tous les articles étudiés, le conditionnement sous vide a été jugé indispensable, car il empêche la dessiccation et le rancissement durant l'entreposage frigorifique. En outre, il peut concourir, de diverses manières, à la préparation des produits. Par exemple, les filets de hareng (*Clupea harengus*) en barquettes d'aluminium sont recouverts d'un mélange de chapelure et de beurre aromatisé, qui est réparti également sur leur surface sous l'effet de la pression qu'exerce le conditionnement sous vide. Un autre produit (filets de hareng marinés) est congelé autour d'un bâtonnet: c'est l'effet combiné de la pression de l'emballage sous vide et de la congélation qui provoque l'adhérence de la chair de hareng au bâtonnet, même après plongée dans la friture. Dans un troisième cas, diverses herbes et épices sont placées entre deux filets; le produit est ensuite emballé sous vide, ce qui provoque entre les condiments et la chair de poisson un contact étroit qui assure leur absorption par celle-ci, et le poisson "gravad" peut alors être congelé. En conclusion, l'auteur décrit la forme qui est donnée aux blocs congelés de filets servant de produits semi-finis pour diverses fabrications. Celle-ci vise à réduire au minimum les fuites dans les sachets de plastique après conditionnement sous vide des produits finis.

Técnicas de envase al vacío y de preparación de productos

Se dan los varios ejemplos de la aplicación de la técnica de envase al vacío a la preparación de nuevos productos pesqueros congelados. Los productos son del tipo llamado "pronto para usos culinarios", empaquetados en bolsas de plástico. El envasado al vacío ha resultado indispensable para todos los productos descritos porque impide que el pescado se seque y se enrancie durante el almacenamiento en frigorífico. Además, esta técnica del vacío puede facilitar de diversas maneras la fabricación de los productos: por ejemplo, los filetes de arenque (*Clupea harengus*) envasados en bandejas de aluminio, se cubren con una mezcla de mantequilla aromatizada y de pan rallado: la presión producida por el envase al vacío hace que esta mezcla se extienda parejamente sobre la superficie del arenque. Otro producto, los filetes de arenque marinados, se arrollan a una varilla y se congelan. La presión producida por el envase al vacío, sumada al procedimiento de congelación, hace que el arenque se adhiera a la varilla incluso después de freirlo en mucho aceite o grasa. En un tercer producto, se colocan diferentes clases de hierbas y especias entre dos filetes, que después se envasan al vacío, lo que produce un estrecho contacto entre la carne del pescado y las sustancias aromáticas, que hace que éstas sean fácilmente absorbidas y entonces puede congelarse el pescado así "grabado". Se describe por último la forma de los bloques congelados de filetes, que constituyen una semi-manufactura para diferentes tipos de productos. El objeto de darle forma a los bloques es reducir al mínimo las pérdidas de las bolsas de plástico después de efectuado el envase al vacío del producto acabado.

At the Technological Laboratory of the Danish Ministry of Fisheries, the development of new fish products has been part of the work for several years. This paper describes some examples of the product development in the frozen fish sector, which has taken place in recent years at the Laboratory. Some of the products, which will be described, have already been marketed by the Danish fishing industry, others are ready for production, and still others need some more laboratory investigations prior to introduction to the industry.

A common feature of the products is that they all belong to the so-called ready-to-cook type of food, vacuum-packed in suitable plastic pouches. The vacuum packaging technique has been found indispensable, because it offers an excellent protection of the fish against desiccation and development of rancidity during cold storage. Besides, this technique has been found to facilitate the industrial manufacture of some products. On the other hand, one is faced with special problems in the manufacture of other products, especially those vacuum-packed from the frozen state. Examples will be given in the following.

EXAMPLES OF PRODUCT DEVELOPMENT

Packaging of pre-frozen products

Two different types of frozen cod (*Gadus morhua*) products prepared from the same semi-manufacture, *viz.* a block of frozen cod fillets, are given in figs 1 and 2.

Fig 1 shows a boil-in-the-bag product, where two slices of frozen cod fillets, a piece of flavoured butter and a slice of lemon are vacuum-packed in a pouch of polyester/polyethylene laminate. On the flap is printed the net weight, the price, the keeping qualities of the fish at different temperatures, and a recipe for the preparation of the fish. The fish is prepared by merely putting the

Fig 1. Boil-in-the-bag cod product

Fig 2. Baked cod à la Bretagne

pouch with the frozen fish, after removing the flap, into a pot of boiling water. After 15 min the pouch is cut open and fish, lemon and butter sauce are placed on a dish ready for serving. If wanted, the butter sauce and fish juice (or drip) may be combined with different ingredients to special kinds of sauces.

Fig 2 shows the same two slices of frozen cod fillets covered with a mixture of breadcrumbs and flavoured butter with slices of almonds on top. The product is vacuum-packed in a pouch of cellophane/polyethylene laminate placed in an aluminium tray. An outer plastic pouch of polyethylene keeps the tray and the vacuum-packed fish slices together. The kitchen preparation consists in removing the two plastic pouches. The frozen fish in the aluminium tray is then placed in an oven and baked for 30 min, and the "Baked cod à la Bretagne" is ready for serving.

The above-mentioned two products are now manufactured by the same factory, which derives advantage from being able to produce different products from the same semi-manufacture.

In fig 3 are given various stages in the development of the boil-in-the-bag product, starting from below. This development includes among other things the portion size, the attractive appearance of the product, the right dosage technique of the butter mixture, and the right packaging technique to be applied to the fillets in the block. These things shall not be commented on here, only the shape of the blocks, from which the slices of frozen cod are cut. As can be seen from fig 3, the final product has rounded edges. This has been obtained by freezing the fillets in a "trough". The first two versions of the product, as shown below in fig 3, had sharp corners, where three surfaces joined. This was very often found to cause a leakage of the plastic pouch after vacuum packaging. Pieces with rounded edges were less liable to lose the vacuum, and this form was, therefore, chosen in the final product (fig 1).

When the boil-in-the-bag product was marketed, there were still too many pouches without vacuum in the shops. Thus, our laboratory investigated 100 pouches in order to find out where these pouches were leaking. One hundred pouches had a total of 117 leakages, and 45 per cent of these were found along the edges of the fillet block, including 19 per cent which had developed in the corners. Thirty-eight per cent of the leakages were found on the front and back of the pouch, while 12 per cent of the holes developed around the welding seams.

Among the different methods of attacking the problem it was chosen to try to improve the strength and the toughness of the plastic film. The polyethylene layer in the laminate was made thicker, and it seems as if this procedure has solved the problem. One might also have used another plastic type, for instance a laminate, where polypropylene had replaced polyethylene, or a non-laminate of the polyamide type. Other possibilities of minimizing the loss of vacuum were to put the pouch into a protective carton or to change the shape of the product. This, however, would no doubt have detracted from the popularity of the article in the supermarkets.

In conclusion it should be said that vacuum packaging of already frozen products makes special demands to the shape of the product. Sharp corners or points should be avoided, because the hard frozen product, unlike the soft fresh fish, will not get a smooth surface from vacuum packaging and, thus, the plastic pouches will be more exposed to leakage during cold storage and distribution.

Fig 3. Various stages in the development of the boil-in-the-bag cod product shown in fig 1

Vacuum packaging as part of the manufacture

Pan herrings. Since ancient times, herring (*Clupea harengus*) have been a common foodstuff in Denmark, consumed in many different ways. Today the Danish fishery for herring is still extensive. As landings are huge, prices are low and great quantities of herring are used in the fish meal production. On this background and because of the high nutritive value of herring, our laboratory has been taking an increasing interest in developing herring products.

One of the most common methods of preparing fresh herring in Denmark is to fry the fish in a pan, and fig 4 shows a product to be prepared in that way. In fig 4(a) the frozen product is vacuum-packed in a pouch of cellophane/polyethylene laminate. It consists of two breaded herring fillets, between which are placed different herbs and a stuffing of herring meat and spices. Of course, a product with such a high fat content has to be vacuum-packed, if development of rancidity is to be avoided. Besides, the vacuum packaging helps to keep the edges of the fillets close together so that herbs and stuffing will stay between the fillets, even when the product is frozen under pressure in a plate freezer. Freezing in a plate freezer is done to flatten the surface of the product. As it is going to be fried in a pan (fig 4(b))

Fig 4(a). Frozen pan herrings

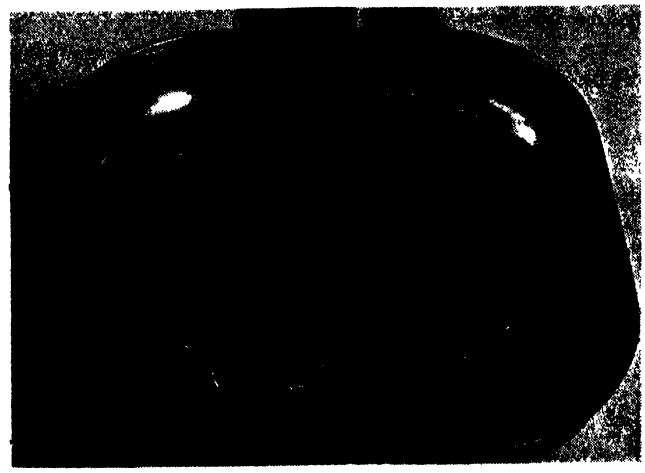


Fig 4(b). Pan herrings during kitchen preparation

from the frozen state, it is important that there be a close contact between the surface of the pan and the whole surface of the fish in order to get an effective transfer of heat. After freezing, the two fillets and the stuffing will stick together, even when fried.

Baked herrings. Fig 5 shows, on the right, a frozen, vacuum-packed product of herring, which is to be prepared by baking in an oven. Boned herrings, which have been treated in a special way to avoid development of rancid odours during preparation in the kitchen, are here packed together with a mixture of breadcrumbs, flavourings and shortenings in an aluminium tray. It is seen that the plastic pouch covers both the herrings and the aluminium tray. The dish is prepared after removing the plastic pouch (cellophane/polyethylene laminate), and the tray with the frozen herrings is placed in the oven. After 30 min the herrings are ready for serving, having obtained a crisp brown crust.

In addition to protecting the frozen product against development of rancidity and desiccation, the vacuum packaging plays an important role in the manufacture of the product. Fig 5 shows how the mixture of breadcrumbs, flavourings and shortenings is spread over the

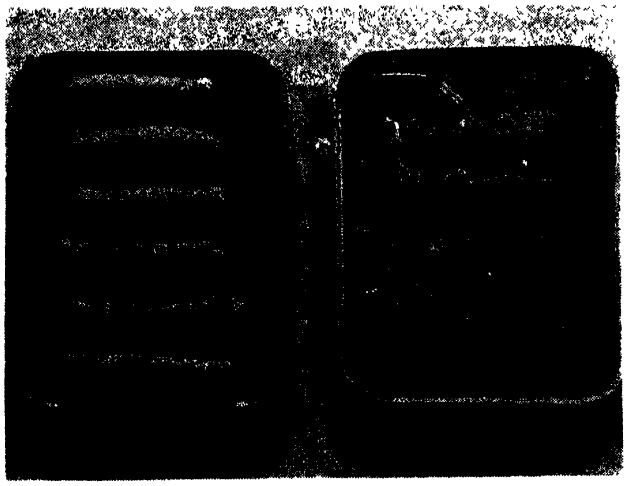


Fig 5. Baked herrings. (Left) a mixture of breadcrumbs and flavoured butter has been sprayed on the back of the fillets. (Right) the distribution of the mixture after vacuum packaging in a plastic pouch

surface of the product. This mixture forms the crust in baking. The fresh herrings are packed in the tray and the mixture is spread over the fish (fig 5, on the left). The vacuum pressure will give an even distribution of the mixture as seen in fig 5, on the right. It is on purpose that a border along the edges of the aluminium tray is not covered. In our opinion the product presents a more attractive appearance, when the consumer can see the main ingredients of the product. With this end in view we try to avoid placing the various vacuum-packed dishes, shown in this paper, in an outer carton.

Herrings-on-sticks. A third product made from herring is shown in fig 6. It consists of boned herrings marinated in a seasoned marinade. After breading, one herring is placed around a stick and put into a pouch of cellophane/polyethylene laminate. The pouch is vacuum-packed and

Fig 6(a). Frozen herrings-on-sticks

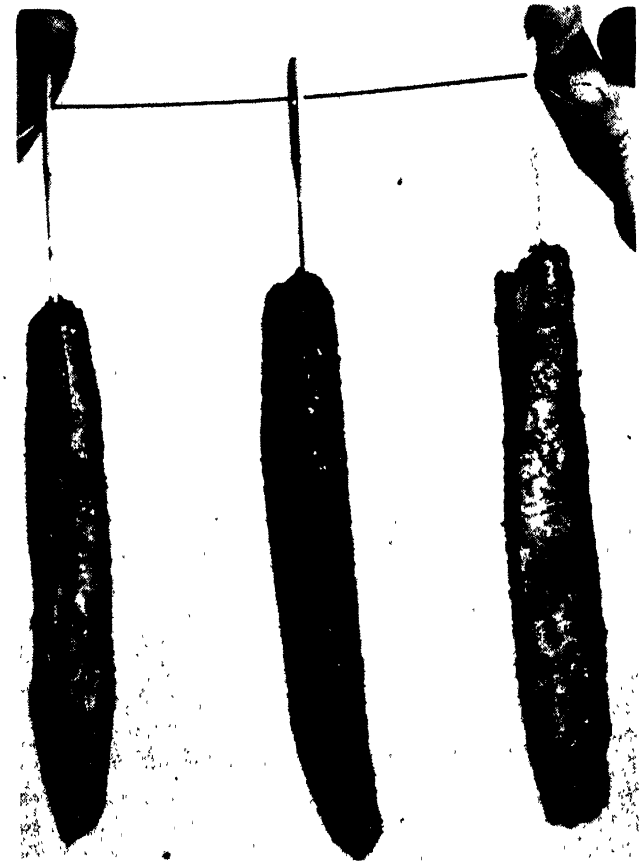


Fig 6(b). The herrings-on-sticks after deep-fat frying

the contents are frozen. The appearance is then as shown in fig 6(a). The preparation takes place by dipping the frozen "herrings-on-sticks" in a 185°C (365°F) hot oil bath for 5 min. Then the deep-fat fried product gets a crisp crust, it still adheres to the stick (fig 6(b)), and it may be regarded as a quick meal to be eaten in snack bars, etc.

With this product, vacuum packaging forms an integral part of the manufacture, making the product look like a herring on a stick and the fillet adhere to the stick even after deep-fat frying. Besides, vacuum packaging always protects the fish during cold storage.

"Gravad" mackerel. The product shown in fig 7 is made from mackerel (*Scomber scombrus*), which has been "gravad" in the fresh state and then frozen.

The "grava" technique is commonly used in the Scandinavian countries as a means of preparing salmon (*Salmo salar*), in particular, but also herring and mackerel. Various procedures are used to "grava" fish. In the most common procedure, salmon and mackerel are filleted. A mixture of common salt, sugar and spices (mostly dill) is placed between two fillets. The raw fillets are then placed in a dish under pressure to obtain contact between the meat surfaces and the flavouring agents. Then the fillets are placed in a refrigerator for 24 h. During this period the fillets must be turned at least once to prevent the exuded juice with the flavourings from gathering around the bottom fillet. After 24 h the spices are removed and the meat is ready for consumption. The fillets are normally cut into thin slices, and the raw "gravad" meat may be served with a dressing of oil, vinegar and mustard together with bread and butter.

Fig 7. "Gravad" mackerel during "grava"-ing prior to freezing

The product shown in fig 7 is "gravad" with the same ingredients as in normal kitchen preparation. The ingredients are placed between two fillets, which are then put into a plastic pouch (cellophane/polyethylene laminate) and vacuum-packed. The pouch is kept at 0°C (32°F) for 24 h and immediately afterwards frozen and cold stored. In the final kitchen preparation the "gravad" mackerel is thawed in the pouch and treated like a fresh "gravad" fish.

By introducing vacuum packaging in the "grava" technique several advantages are obtained, facilitating an industrial production.

(1) The vacuum pressure gives a close contact between fillets and spices.

(2) It keeps the edges of the fillets close together and therefore the exuded fluid stays between the fillets, and consequently the fillets need not be turned during "grava"-ing.

(3) No outer contamination of the fish will happen, while it is being "gravad".

(4) When the product has been "gravad" it is ready for freezing and distribution.

"Gravad" mackerel is among the products which are still being investigated at the laboratory. We want to find out, for instance, whether vacuum packaging of the product will retard the development of rancidity and thus make the keeping quality of the frozen product satisfactory. It should be remembered that the combination of a fatty fish, like mackerel, and a pro-oxidant, like sodium chloride, is normally not to be recommended. Earlier experiments with lightly-salted shrimp (*Pandalus borealis*) and salmon, however, have been promising as to the storage times of the frozen, vacuum-packed products. The salt content, though, was only a few percent, while the "gravad" mackerel contains 6 per cent salt.

Development of Fish Products with Particular Reference to Frozen Minced Fish Muscle (Surimi)

by E. Tanikawa, T. Motohiro and M. Akiba

Development of fish products with particular reference to frozen minced fish muscle (surimi)

Frozen minced fish muscle (surimi) is used as a raw material for the manufacture of Japanese-style fish pastes such as kamaboko and in making fish sausages and hams.

The paper describes experiments in the manufacture of surimi from squid (*Ommastrephes sloani pacificus*), cod (*Gadus macrocephalus*), Alaska pollack (*Theragra chalcogramma*) and Atka mackerel (*Pleurogrammus azonus*) using additives such as polyphosphates, sugars, starches, egg-white, shortening oils, etc., to decrease the thaw drip and improve the elasticity of the final cooked paste.

It was found that the addition of sugar (cane sugar, glucose or sorbitol) and polyphosphate improved the keeping quality. The addition of egg-white was also effective, particularly in improving raw fish pastes of low elasticity. Starches and shortening oils were also beneficial but their addition might not be economical since sugars and polyphosphates were also needed. Leaching of the minced fish to remove soluble matter prior to freezing also had a desirable effect on the finished product. In general, Atka mackerel produced a more elastic final product than did squid, cod or Alaska pollack.

The authors also briefly describe experiments in the removal of the skin from squid by using enzymes from squid or crab livers and by using lactic acid.

Preparation de produits à base de poisson, et plus particulièrement de "surimi" (muscle de poisson haché et congelé)

Le muscle de poisson hâché et congelé (surimi) sert de matière première pour la fabrication de pâtes de poisson à la mode japonaise comme le kamaboko, ainsi que pour la préparation de saucisses et de "jambons" de poisson.

La communication décrit des essais de fabrication de "surimi" à partir d'encornet (*Ommastrephes sloani pacificus*), de morue (*Gadus macrocephalus*), de colin d'Alaska (*Theragra chalcogramma*), et de maquereau d'Atka (*Pleurogrammus azonus*), avec emploi d'additifs tels que polyphosphates, sucres, amidons, blanc d'oeuf, shortenings de type huileux, etc., afin de réduire l'exsudat à la décongélation et d'améliorer l'élasticité de la pâte cuite à son stade final.

On a constaté que l'adjonction de sucre (sucre de canne, glucose ou sorbitol) et de polyphosphate améliorait la conservabilité. L'addition de blanc d'oeuf donne aussi de bons résultats, notamment pour améliorer les pâtes de poisson crues peu élastiques. Les amidons et les shortenings de type huileux se sont également révélés utiles, mais leur emploi risque de n'être pas rentable, car il ne permettent pas de se passer des sucres et des polyphosphates. Le lessivage du poisson hâché, effectué afin d'éliminer les substances solubles avant la congélation, permet également d'améliorer le produit fini. Dans l'ensemble, le maquereau d'Atka donne un produit plus élastique que l'encornet, la morue ou le colin d'Alaska.

Enfin, les auteurs décrivent brièvement des essais d'utilisation d'enzymes retirés du foie de l'encornet ou du crabe ou d'acide lactique dans le dépiautage des encornets.

La preparación de productos pesqueros con especial referencia a "surimi" o carne de pescado picada y congelada

La carne de pescado picada y congelada (surimi) se emplea como materia prima para la fabricación de pastas de pescado a estilo japonés, tales como kamaboko, y para hacer embutidos y "jamones" de pescado.

El estudio describe los experimentos de fabricación de surimi con calamares (*Ommastrephes sloani pacificus*), bacalao (*Gadus macrocephalus*), abadejo de Alaska (*Theragra chalcogramma*) y caballa Atka (*Pleurogrammus azonus*) empleando aditivos tales como polifosfatos, azúcares, almidones, clara de huevo, aceites de manteca vegetal, etc., para reducir el exudado y mejorar la elasticidad de la pasta final preparada.

Se comprobó que la adición de azúcar (azúcar de caña, glucosa o sorbitol) y de polifosfato mejoró el mantenimiento de la calidad. También fué eficaz la adición de clara de huevo, especialmente para mejorar las pastas de pescado crudo de poca elasticidad. Las féculas y los aceites de manteca vegetal fueron igualmente convenientes, pero es posible que no sea económico agregarlos porque se necesitan también azúcares y polifosfatos. La lixiviación del pescado picado para extraer las materias solubles antes de la congelación, ejerció un buen efecto en el producto acabado. En general, la caballa Atka dió un producto final más elástico que los calamares, el bacalao o el abadejo de Alaska.

Los autores describen brevemente los experimentos realizados para quitar la piel a los calamares por medio de enzimas de calamares o de hígados de cangrejos y empleando ácido láctico.

KAMABOKO (Japanese-style fish paste) has been served as a traditional food for the last several hundred years in Japan. Production is still increasing up to the present day, and can be expected to increase further. On the other hand, though fish sausage and ham production has only been started from the end of the Second World War, this has become popularized by the development of packaging materials and preservatives.

Suitable species are, for example, lizard fish (*Saurida argyrophanes*), a kind of croaker (*Nibea mitsukuri*) and stroptoothed eel (*Muraenesox cinereus*). These can be used as raw material for making kamaboko. Fish ham and sausage is mainly made from tuna. Increase of catching effort, however, has resulted in a steady decrease in the resources of the sea around Japan. The situation has resulted in the use of some species of fish such as Alaska pollack (*Theragra chalcogramma*) and Atka mackerel (*Pleurogrammus azonus*) as a new raw material, because these species are still abundant. The catches of Alaska pollack and Atka mackerel are 350,000 to 400,000 t and 150,000 to 200,000 t per year respectively.

One problem is that the elasticity of kamaboko decreases when deteriorated fish is used as raw material. Refrigeration is therefore necessary to keep the fish fresh during transportation and storage, because these fish are usually caught and landed at places distant from any processing factory.

A problem which arises from this fact is that denaturation occurs in the muscle proteins of fish kept in frozen storage for a long period.

Only frozen muscle, free from head, bones, etc., is acceptable by processing factories, because of difficulties encountered in disposing of waste and in obtaining labour. Frozen minced fish muscle (surimi) has therefore tended to be used as raw material for kamaboko, fish sausage and ham. This is a result of a need to minimize

the handling of raw fish and to reduce the number of operations in processing plants.

There are now 55 plants and two floating factories producing frozen minced fish muscle in Japan. They produce 60,000 t of frozen minced fish muscle from 200,000 t of raw fish per year.

This paper reports some technical problems encountered in preparing frozen minced fish muscle.

GENERAL METHOD OF PREPARING FROZEN MINCED FISH MUSCLE

Frozen minced fish muscle is prepared generally by the following procedure. Raw fish are beheaded and eviscerated. After washing, the muscle is separated from the bones and skin by means of a meat-separating machine, in which the fish are pressed by means of a plunger. Under pressure the muscle is forced through a perforated iron disc, being separated from the bones and skin which remain behind. The flesh is either soaked in water in a tank or rinsed with running water. This has the effect of removing blood, inorganic substances and water-soluble proteins. Excess water is removed, either with a hydraulic press or by means of a centrifugal dehydrator. The partially dehydrated material is crushed with a chopper and ground in a stone grinder, where various additives such as sugars and polyphosphates are added. Finally, the minced muscle is frozen at −25° to −30°C (−13.0° to −22.0°F) and stored at −20°C (−4.0°F).

Denaturation of the protein is an important technical problem in the storage of frozen fish muscle, because the protein of fish is easily denatured by mechanical action or the freezing procedure (Yoshimura *et al.*, 1951; King, 1962). As a means of preventing the denaturation of the proteins in frozen material, the leaching of the flesh to remove inorganic substances and water-soluble proteins, and the addition of sodium tripolyphosphate and sodium pyrophosphate (1 : 1) and cane sugar (or glucose or sorbitol) were introduced (Nishiya, 1963). It is now possible to store frozen minced fish muscle without deterioration for three months by using this method.

PREVENTION OF DENATURATION OF PROTEINS IN FROZEN MINCED FISH MUSCLE

Dehydration always causes the denaturation of the proteins during frozen storage of fish muscle. There are two possible causes of the denaturation during storage. One of these is a salting-out effect, that is, the concentration of tissue salts, usually 1.0 to 1.5 per cent in raw fish muscle is increased by freezing, and the concentrated material has a harmful effect on the proteins. Secondly, syneresis of actomyosin may result in mutual aggregation of the protein molecules by freezing, and this results in a change in the natural disposition of the actomyosin.

Denaturation of proteins in frozen fish muscle depends on various conditions. Notevarp and Heen (1940) and Simidu and Simidu (1957) have found that icing prior to freezing had caused a decrease in the quality of the frozen fish. The degree of protein denaturation evidently differs with condition of the fish before freezing.

When sliced cod muscle and fillet are frozen at −25°C (−13.0°F) and then stored at −10°C (14.0°F), the proteins denature rapidly within 20 days, but the degree of denaturation is greater in the sliced muscle than in fillets. This fact suggests that mechanical grinding of fish muscle may be a factor causing denaturation of proteins, and any insufficient pre-treatment or addition of additives must cause a decrease in quality of frozen minced fish muscle. Removal of water soluble substances by leaching and adding sugars and polyphosphates into the mince effectively inhibit deterioration.

The present authors have tested the effectiveness of leaching and additives on the quality of frozen minced fish muscle.

Frozen minced products from squid muscle were prepared as follows: the cephalopoditic and fin parts (without mantle cavity) which are by-products from the processing of seasoned smoked squid, were soaked in water at 55° to 65°C (131° to 149°F) for 10 min to remove the skin. They were then leached with solutions of 0.5 per cent hydrogen peroxide and sodium hypochlorite in 10 ppm concentration for 15 min. They were minced and kneaded. Various kinds of additives were mixed with the muscle during grinding. The minced muscle was placed in a vessel which contained 7 kg, and covered with a polyethylene sheet, frozen at −27°C (−16.6°F), and then stored at −18°C (−0.4°F). Thirty-seven kinds of samples including the control were prepared by mixing different additives into the minced muscle (figs 1 and 2).

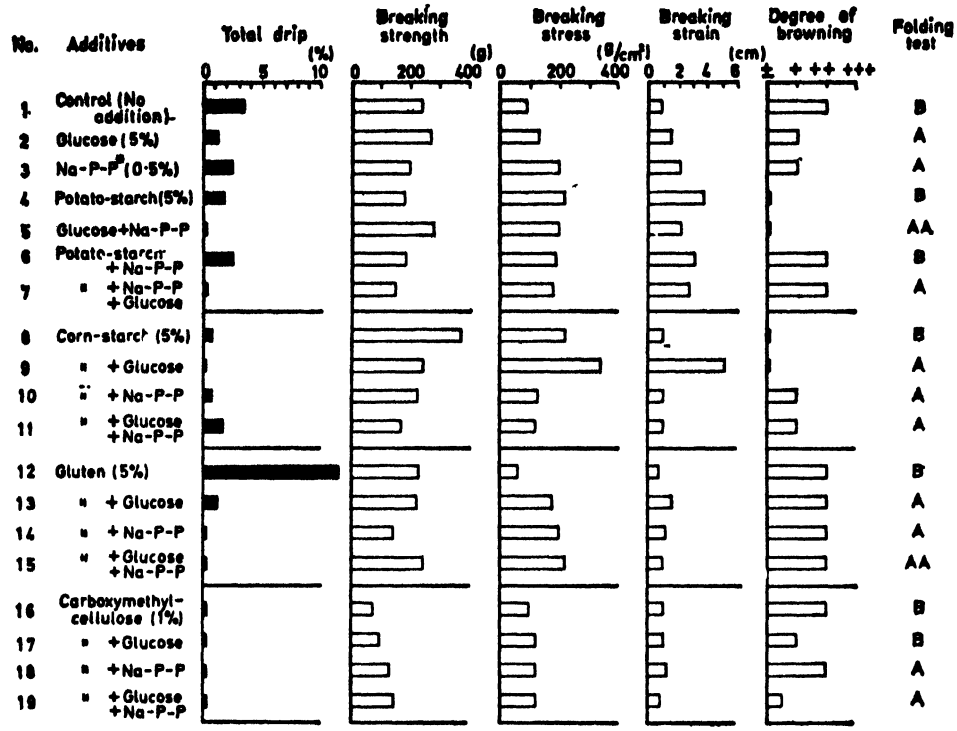
Frozen minced Alaska pollack muscle was prepared as follows: after grinding, the raw paste was allowed to stand overnight in three parts by volume of water, then centrifuged. This reduced the water content to 82 per cent. Various kinds of additives were afterwards mixed with the minced product. Finally, the minced muscle was covered with a polyethylene sheet, frozen and stored at −26°C (−14.8°F). As shown in figs 3 to 5, 53 kinds of samples were prepared.

Frozen minced muscle from cod (*Gadus macrocephalus*) was prepared by the following procedure. The samples were divided into two groups. One was leached with water and the other was not. The 11 samples were prepared as shown in fig 6. The samples were frozen and stored at −26°C (−14.8°F).

Frozen minced muscle from Atka mackerel, consisting of leached and unleached groups, were prepared as described above. Fifteen samples shown in fig 7 were frozen and stored at −26°C (−14.8°F).

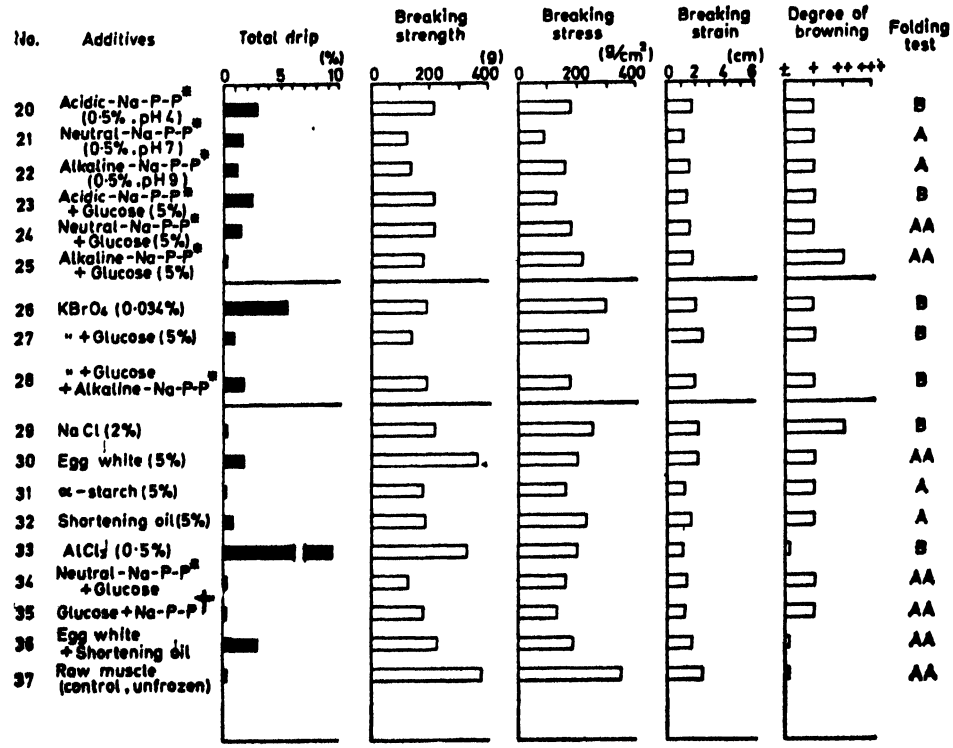
Additives used were as follows: (1) high molecular weight substances—potato and corn starches, α-starch, carboxymethylcellulose, raw egg white, gelatin, gluten, sodium polyacrylate; (2) propylene glycol; (3) fats—plant and shortening oils; and (4) inorganic substances—potassium bromate, aluminium chloride and sodium chloride. The materials were mixed with raw minced fish muscle with or without sugars and polyphosphates. The amount of these materials added to the minced fish muscle are described in figs 1 to 7 also.

The frozen minced fish muscle after storing was allowed to stand overnight at 10°C (50°F) for defrosting. The degree of discolouration and the quality of the defrosted paste were estimated organoleptically. The volume of fluid from a portion of the defrosted paste was then measured. In addition to the free fluid which drained



* A mixture of sodium tripolyphosphate and sodium pyrophosphate (1 : 1)

Fig 1. Results of experiments on frozen squid muscle paste (1) (frozen temperature, −27°C (−16.6°F); storage, −18°C (−0.4°F); after 90 days)



* A special sodium polyphosphate, named as "Adecarin".
† A mixture of sodium tripolyphosphate and sodium pyrophosphate (1 : 1).

Fig 2. Results of experiments on frozen squid muscle paste (2) (frozen temperature −27°C (−16.6°F); storage, −18°C (−0.4°F); after 90 days)

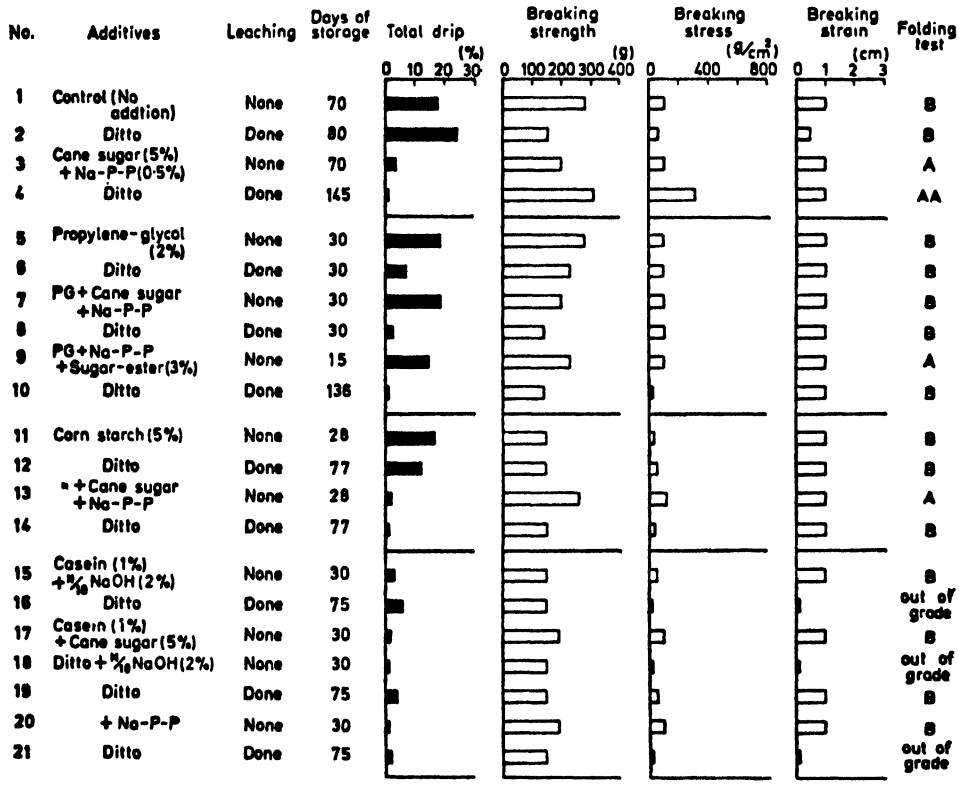


Fig 3. Results of experiments on frozen Alaska pollack muscle paste (1) (frozen storage at −26°C (−14.8°F))

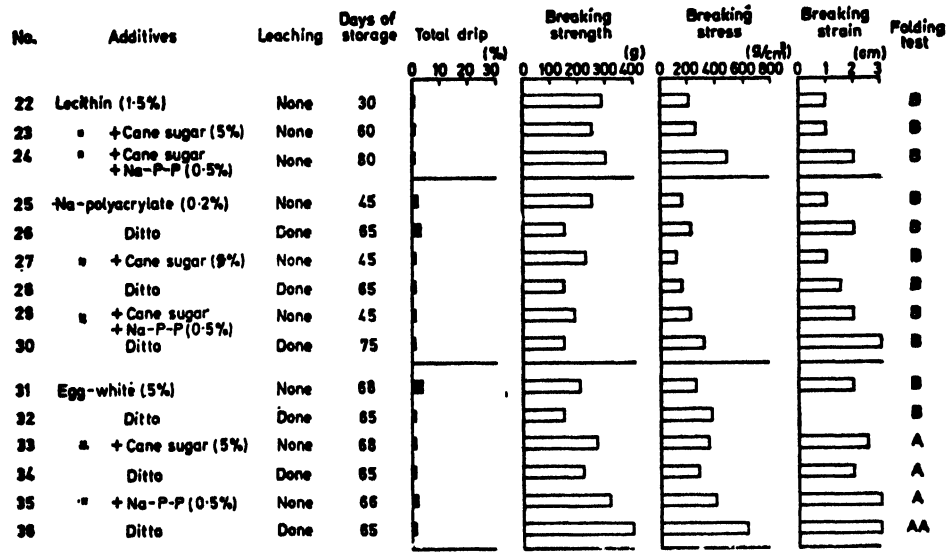


Fig 4. Results of experiments on frozen Alaska pollack muscle paste (2) (frozen storage at −26°C (−14.8°F))

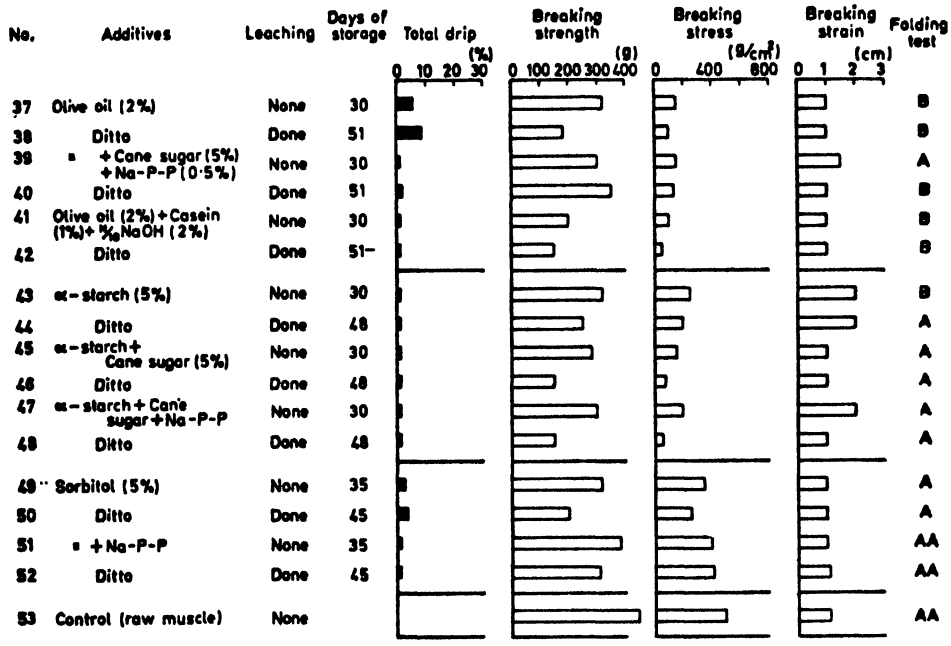


Fig 5. Results of experiments on frozen Alaska pollack muscle paste (3) (frozen storage at −26°C (−14.8°F))

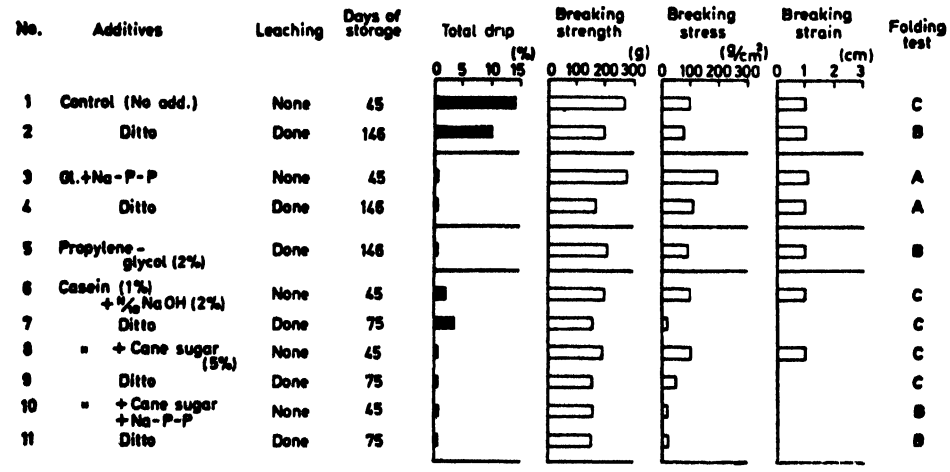


Fig 6. Results of experiments on frozen cod muscle paste (frozen storage at −26°C (−14.8°F))

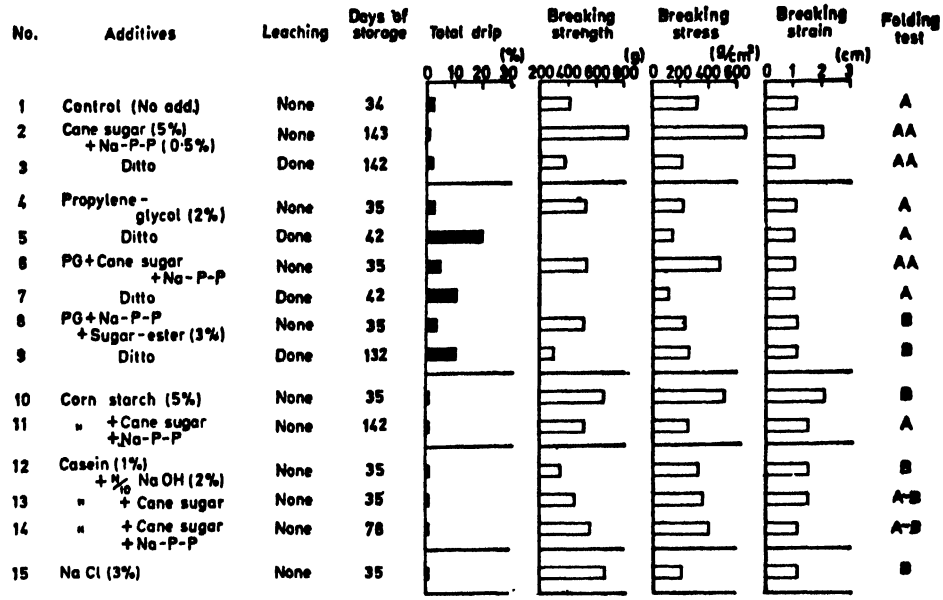


Fig 7. Results of experiments on frozen Atka mackerel muscle (frozen storage at −26°C (−14.8°F))

out from the paste during defrosting, expressible fluid was obtained by hand pressing [about 0.5 kg/cm² (7 lb/in²)]. "Total fluid" was the sum of the free and expressible fluids.

Defrosted pastes which did not already contain them were mixed with sodium chloride (2.7 per cent by weight) and with corn starch (5 per cent). They were then ground for 20 min in a stone grinder and their elasticity and viscosity were assessed organoleptically.

After inspection, about 50 g of the paste was placed in a Petri dish, steamed for 30 min at 90°C (194°F) and left for one night at room temperature to cool. Breaking strength and penetrometer measurements were then carried out by the methods of Matsumoto and Arai (1952) and Shimizu and Simidu (1953). In addition to the above, the paste was evaluated by the folding method of Nishiya (1963), using the following standards with a 3-mm slice of cooked paste.

AA: Flexible and pliable. Does not show cracks on two foldings.
A: Flexible and pliable. Does not show cracks on folding.
B: Breaks halfway through slice on folding.
C: Breaks into two pieces on folding.
D: Breaks into fragments with finger pressure.

The following results were obtained with frozen minced squid muscle. The quality ratings of frozen minced muscle stored for three months at −18°C (−0.4°F) with the various additives are shown in figs 1 and 2.

As shown in fig 2, even when the raw squid muscle was prepared after skinning in hot water, the quality of the product was excellent. Among samples nos. 1 to 36, the following eight were considered to be acceptable for use as the raw material of fish paste kamaboko: (1) samples nos. 5 and 35; (2) sample no. 11; (3) samples nos. 24, 25 and 34; (4) sample no. 30; and (5) sample no. 36.

There was little change in the quality of these samples before and after cold storage and the elasticity of the minced squid muscle which was prepared from these samples was acceptable.

Compared with these samples, the control (no. 1), which had been stored for three months, was of lower quality since it produced a large amount of fluid after defrosting and yielded a lower viscosity on grinding with sodium chloride. On the other hand, the samples which contained additives such as sugars (glucose or cane sugar) and polyphosphates, showed good results. In addition to these additives egg white (5 per cent) or egg white (5 per cent) plus shortening oil (2.5 per cent), respectively, were effective in preserving the quality of the frozen raw fish muscle. With respect to the effect of different starches, corn starch (nos. 8 to 11), was better than potato starch (nos. 4, 6 and 7). Apart from starches, other high molecular substances have shown little effect. Concerning polyphosphates, neutral and alkaline polyphosphates (pH 7.0 and 9.0) were more effective than acidic polyphosphate (pH 4.0). Potassium bromate, which as an additive increased the elasticity in the raw material for raw minced fish muscle (Okada and Nakayama, 1961), was not effective in improving the quality of the frozen product. Sample no. 33 containing aluminium chloride, which is used for soybean paste to prevent discolouration, kept its original colour during frozen storage, though the protein was greatly denatured and gave rise to a large quantity of drip. Thus, the quality of the sample as a raw material for fish paste was inferior to that of the other samples.

The following groups among the samples shown in figs 3 to 5 were usable as additives for minced Alaska pollack muscle:

(1) Cane sugar (5 per cent) and sodium polyphosphate (0.5 per cent). (Samples nos. 3 and 4.)

(2) Egg white (5 per cent), cane sugar (5 per cent) and sodium polyphosphate (0.5 per cent). (Samples nos. 35 and 36.)

(3) Sorbitol (5 per cent) and sodium polyphosphate (0.5 per cent). (Samples nos. 51 and 52.)

Next to these samples described above, the following substances can also be used to improve the quality of this product:

(a) Egg white (5 per cent) and cane sugar (5 per cent). (Sample no. 34.)
(b) α-Starch (5 per cent), cane sugar (5 per cent) and sodium polyphosphate (0.5 per cent). (Samples nos. 47 and 48.)
(c) Sorbitol (5 per cent). (Samples nos. 49 and 50.)

Consequently, the quality of minced Alaska pollack muscle was improved by the addition of sugar (cane sugar and/or sorbitol) and sodium polyphosphate. In addition to these materials, α-starch and egg white are effective in improving the quality of minced Alaska pollack muscle.

Comparing the quality of the product produced with and without the water leaching procedure, the former was always better than the latter. Thus, the leaching procedure is desirable in the preparation of frozen minced fish muscle.

The addition of such materials as propylene glycol (nos. 5 to 10), corn starch (nos. 11 to 14), casein (nos. 15 to 21), lecithin (nos. 22 to 24), sodium polyacrylate (nos. 25 to 30) and olive oil (nos. 37 to 42) to minced fish muscle, did not improve the quality.

In frozen minced cod muscle, the samples (nos. 3 and 4) which contained glucose and sodium polyphosphate showed a good quality during cold storage among the 11 samples tested (fig 6), while the others which contained propylene glycol and casein did not.

In general the frozen minced Atka mackerel is better in its elasticity than that of squid, Alaska pollack and cod. The samples (nos. 2 and 3) which contained cane sugar and sodium polyphosphate showed better quality than those of others containing propylene glycol, corn starch and casein.

It is probable from the results of Kitabayashi (1954) and Miyake and Hayashi (1956) that the proportion of actomyosin extractable in NaCl is related to the elasticity of the fish paste products. Dyer (1951), Simidu and Simidu (1957) and Yoshimura *et al.* (1951) have found that the fibrous proteins ("actomyosin") are denatured during cold storage, while the sarcoplasmic proteins are not affected. The present experiment was also carried out on the assumption that frozen fish muscle in which the "myosins" had become denatured would no longer be usable as the raw material for fish paste products. However, the measurement of protein denaturation during cold storage seems to be somewhat inadequate in this work. Further studies, including measurement of the salt-extractability of the protein, would probably be useful. In the present method for preparing frozen minced fish muscle it is necessary to remove inorganic materials which may cause denaturation of muscle proteins by salting out effect during freezing. For this purpose, the present method includes a leaching procedure. It was found that the addition of sugars including cane sugar, glucose and sorbitol and polyphosphates improved the keeping quality of frozen minced fish muscle. This result was in accord with the finding of Nishiya (1963). Besides the above, egg white was also effective for this purpose. It was pointed out by Oshiro (1959) that egg white was effective in improving the elasticity of raw fish paste products, and that it was especially useful with raw fish meat paste of low elasticity. The effect of egg white in preventing the denaturation of "myosin" in frozen fish muscle during cold storage should be studied. Of all the additives tested, not only egg white but corn starch,

TABLE 1. CONDITION OF THE SKIN OF SQUID DURING SKINNING USING ENZYMATIC ACTION OF SQUID AND CRAB LIVERS

Liver	*Time* (*min*)	*Temperature* (°C) 15	20	25	30
Squid	30	Meat normal Difficult skinning	—	Meat normal Rather easy skinning	—
	60	Meat normal Difficult skinning	Meat normal Dissolve pigment	Meat normal Dissolve pigment Rather easy skinning	Meat softening Dissolve pigment Easy skinning
	120	Meat normal Difficult skinning	Meat normal Dissolve pigment Rather easy skinning	—	Meat softening Dissolve pigment Easy skinning
	180	Meat softening Dissolve pigment Rather easy skinning	Meat softening Dissolve pigment Easy skinning	—	—
	240	Meat softening Dissolve pigment Rather easy skinning	Meat softening Dissolve pigment Easy skinning	—	—
Crab	30	Meat normal Difficult skinning	—	Meat softening Dissolve pigment Rather easy skinning	—
	60	Meat normal Difficult skinning	—	Meat softening Dissolve pigment Easy skinning	—
	120	Meat softening Dissolve pigment Easy skinning	—	—	—
	180	Meat softening Dissolve pigment Easy skinning	—	—	—
	240	Meat softening Dissolve pigment Easy skinning	—	—	—

α-starch and shortening oil are beneficial. Since, however, sugars and polyphosphates need to be used at the same time, they might be uneconomical.

OTHER PROBLEMS IN THE FROZEN MINCED FISH MUSCLE INDUSTRY

Skinning is troublesome in making frozen minced squid muscle. Three different techniques are the skinning by hand, by machine and by autolysis. All are usable only on a small scale, and are unsuitable for large commercial scale. Hand skinning requires much labour and time, while machine or autolysis skinnings are unsatisfactory as they sometimes cause a denaturation of proteins.

The squid skin consists of four layers; the first and second layers are a network of fibrous membranes, and the third and fourth layers are firm, thin membranes of regularly oriented fibres (Tanaka, 1958; Tanikawa and Akiba, 1952). It is therefore easy to skin-off the first and second layers, but difficult to remove the third and fourth.

The present authors have examined a skinning method using enzymes from squid and crab livers. As shown in table 1, the squid skin was easily removed by enzymatic

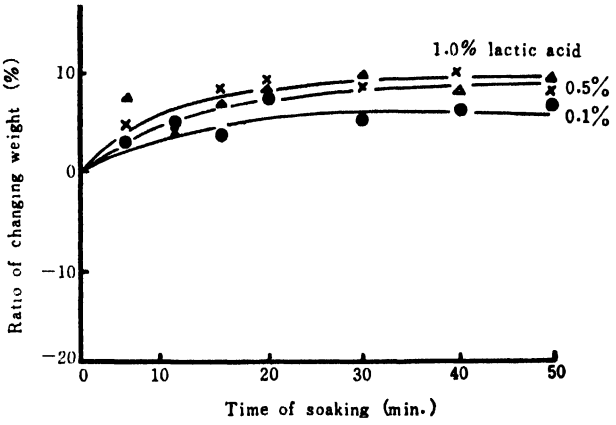


Fig 8. Changes in the weight of surface skin of squid during treatment by lactic acid

action of crab liver. The action, however, could affect squid muscle tissue and result in softening the muscle and dissolving or deforming the melanophores.

It could be possible to skin by means of lactic acid, which converts the collagen of squid skin to gelatin. Changes in the weight of the surface skin of squid during treatment with lactic acid are shown in fig 8. It can be seen that the weight of the skin increased with lapse of soaking time in the solution of lactic acid. This result suggests that gelatinization of the collagen is taking place. It would be useful in practice provided that the muscle proteins in squid could be prevented from denaturing.

Matters to be resolved are the reduction of water needed for making minced fish muscle at floating factories or in factories in which water supply is insufficient, and the development of a method which completely prevents denaturation in the various species of commercial fish.

References

DYER, W J *Fd Res.*, **16**, 522. 1951

KING, F J *Quick froz. Fds int.*, **25**, 115. 1962

KITABAYASHI, K *Bull. Hokkaido reg. Fish. Res. Lab.*, **11**, 105. 1954

MATSUMOTO, J J and ARAI, T *Bull. Jap. Soc. scient. Fish.*, **17**, 1952 373.

MIYAKE, M and HAYASHI, K *Ibid.*, **22**, 48. 1956

NISHIYA, K Special Report of Symposium on Cold Storage of 1963 Fish Meat. *A. Mtg Jap. Soc. scient. Fish.*, p. 211.

NOTEVARP, O and HEEN, E *Z. ges. Kälteind.*, **47**, 122. 1940

OKADA, M and NAKAYAMA, M *Bull. Jap. Soc. scient. Fish.*, **27**, 1961 203.

OSHIRO, Z *A. Mtg. Jap. Soc. scient. Fish.* 1959

SHIMIZU, Y and SIMIDU, W *Bull. Jap. Soc. scient. Fish.*, **19**, 1953 596.

SIMIDU, U and SIMIDU, W *Ibid.*, **23**, 442. 1957

TANAKA, T *Bull. Takai reg. Fish. Res. Lab.*, **20**, 77. 1958

TANIKAWA, E and AKIBA, M *Bull. Fac. Fish. Hokkaido Univ.*, 1952 **3**, 81.

YOSHIMURA, K, KUBO, S, SOMA, T and MURAKAMI, K *Bull.* 1951 *Jap. Soc. scient. Fish.*, **17**, 74.

Effect of Sodium Citrate on the Keeping Quality of Frozen Surimi (Frozen Fish Paste)

by M. Okada

Effect of sodium citrate on the keeping quality of frozen surimi (frozen fish paste)

It is well known that some species of fish such as Alaska pollack (*Theragra chalcogramma*) deteriorate so rapidly during storage in the frozen state that these fish cannot be used as material for kamaboko manufacture. Recently, a new frozen product, surimi (fish paste), has been developed in order to overcome the deficiency. Two kinds of frozen surimi, namely unsalted surimi and salted surimi are available. The latter type of surimi is made as follows: after washing with cold water, the crushed fish meat is ground with 3 per cent of sodium chloride and 10 per cent sugar to sticky paste, and quickly frozen.

It has been found that the reason the salted surimi cannot be used for kamaboko after four or five months' storage at −25°C (−13°F) is because of the jelling of the myofibrillar proteins and that the addition of sodium citrate in combination with sugar significantly improves the keeping quality of the product by retarding this jelling action.

Influence du citrate de sodium sur la conservabilité du surimi (pâte de poisson) surgelé

On sait que certaines espèces de poissons tels que le colin d'Alaska (*Theragra chalcogramma*) s'altèrent si rapidement durant l'entreposage à l'état congelé que ces poissons ne peuvent servir de matière première pour la fabrication du kamaboko. Pour remédier à ce défaut, on a récemment mis au point un nouveau produit surgelé, le surimi (pâte de poisson), dont il existe deux types: le surimi non salé et le surimi salé. Ce dernier est préparé de la manière suivante: après lavage à l'eau froide, la chair du poisson est hâchée avec 3 pour cent de chlorure de sodium et 10 pour cent de sucre, ce qui constitue une pâte épaisse, qui est alors surgelée.

On a constaté que si le surimi salé ne peut servir à la fabrication de kamaboko après quatre ou cinq mois d'entreposage à −25°C c'est à cause de la gélification des protéines myofibrillaires, et que l'adjonction de citrate de sodium et de sucre améliore considérablement la conservabilité du produit en retardant cette gélification.

El efecto del citrato de sodio en la calidad de conservación del surimi congelado (pasta de pescado congelada)

Como se sabe bien, ciertas especies de peces tales como el abadejo de Alaska (*Theragra chalcogramma*) se deterioran tan rápidamente durante su almacenamiento en estado congelado que no se pueden utilizar para fabricar kamaboko. Para vencer esta dificultad se ha creado recientemente un nuevo producto congelado: el surimi (pasta de pescado). Existen dos clases de surimi congelado, a saber: el surimi sin sal y el salado. Esta última clase se obtiene del modo siguiente: después de lavarla con agua fría, la carne de pescado triturada se muele con un 3 por ciento de cloruro de sodio y un 10 por ciento de azúcar hasta formar una pasta pegajosa y se congela rápidamente.

Se ha comprobado que la razón de que el surimi salado no sirva para fabricar kamaboko, después de un período de almacenamiento de 4 a 5 meses a −25°C (−13°F), se debe a la gelificación de las proteínas miofibrilares, y a que la adición de citrato de sodio mezclado con azúcar mejora muchísimo la calidad de conservación del producto retardando dicha gelificación.

FROZEN surimi has been developed in order to improve the keeping quality of such fish as Alaska pollack (*Theragra chalcogramma*) which are not satisfactory for kamaboko after a short storage. As frozen surimi has the advantage of easy transport and storage in addition to its good keeping quality, the annual production amounted to 40,000 t in 1966.

There are two kinds of frozen surimi in Japan; one is unsalted surimi which is prepared by freezing well-washed comminuted fish meat containing 5 per cent sugar and 0.3 per cent polyphosphate. The other is salted surimi which contains 3 per cent sodium chloride and 10 per cent sugar. While salted surimi produces better kamaboko than unsalted surimi it is unsatisfactory after four or five months' storage. Unsalted surimi, however, keeps well for at least 10 months at −20°C (−4°F).

Preliminary experiments indicated that salted surimi was not usable for kamaboko because the meat jelled during cold storage. This phenomena is often observed when fish meat is ground with 2 to 3 per cent salt to a sticky paste and kept at room temperature for 12 to 24 h. Migita and Okada (1963) explained the setting in terms of the formation of a network structure of myofibrillar proteins. They found that the rate of setting depends a great deal on the temperature as well as on the nature of anions of salts added to fish meat. For example, the presence of alkali metal salts of sulphate, citrate or tartrate appreciably retard the jelling.

It was expected that salted surimi with a good shelf life could be obtained by addition of salts, such as mentioned above, to retard jelling of the fish meat during storage. The present study was undertaken to determine the effect of sodium citrate on the keeping quality of frozen salted surimi.

EXPERIMENTAL METHODS

Sample preparation

Fish used in the study was Alaska pollack which had been stored for two days in ice after being caught by trawling. The meat was separated by a meat separating machine and divided into two portions. One portion was washed well with cold water and pressed in order to remove excess water. The other portion was not washed. Both washed and unwashed samples were divided into several parts after mincing with a meat chopper. The ingredients shown in table 1 were added to each part and mixed well in a mortar. During these treatments, the temperature of fish meat was kept below 5°C (41°F).

TABLE 1. FORMULATION OF FROZEN SURIMI INGREDIENTS

No.	*Meat*	*NaCl* (%)	*Sugar* (%)	*Na-citrate* (%)
1	Washed	3	10	3
2	,,	3	5	3
3	,,	3	0	3
4	,,	3	10	1.5
5	,,	3	5	1.5
6	,,	3	0	1.5
7	,,	3	10	0
8	,,	3	0	3
9	Unwashed	3	10	3
10	,,	3	5	3
11	,,	3	0	3
12	,,	3	10	1.5
13	,,	3	5	1.5
14	,,	3	0	1.5
15	,,	3	10	0
16	,,	3	0	3

The samples were packed in polyethylene bags and frozen quickly in a plate freezer at −35°C (−31°F), and then stored at −25°C (−13°F) for one year. At intervals, samples were taken out and left at 5°C (41°F) to thaw to evaluate the degree of jelling and its acceptability for making kamaboko.

Evaluation of jelling

The degree of jelling of the thawed surimi was judged organoleptically on the standard form shown in table 2.

TABLE 2. SCORING SCALE FOR THE EXTENT OF JELLING OF FISH MEAT PASTE

Sticky paste	1
Less sticky paste	2
Elastic jelly	3
Very elastic jelly	4

Determination of the acceptability of the paste for use in kamaboko

Its acceptability was determined by a standard method. The thawed surimi was ground in a mortar for 20 min. The ground surimi (5°C, 41°F) was packed into a casing and cooked in 85°C (185°F) water for 40 min. The jelly thus obtained was held overnight and scored on a point system for elasticity and texture shown in table 3. On this scale, the borderline for practical use in the kamaboko industry is defined by a score of 4.5.

Elasticity was also measured objectively with a plunger-type jelly meter and its water-holding capacity by a pressing method. Since a fairly good correlation was observed between the taste test and these objective measurements, only the results of the taste test are shown in this paper.

TABLE 3. SCORING SCALE FOR ELASTICITY OF KAMABOKO

Excellent	10
Good	9
	8
Satisfactory	7
	6
Unsatisfactory	5
	4
Poor	3
	2
Completely unacceptable	1
	0

Effect of sodium citrate

Fig 1 shows that a regular frozen surimi prepared by a procedure that closely paralleled commercial practice, namely by freezing well-washed meat containing 3 per cent NaCl and 10 per cent sugar, remains acceptable for kamaboko for four months' storage at −25°C (−13°F). However, its acceptability decreases very rapidly during the following two months and after six months' storage it cannot be used as a material for kamaboko. These experimental results agree with the fact that the shelf life of commercial frozen salted surimi at −20° to −25°C (−4° to −13°F) is about four or five months.

Fig 1(a) shows also that frozen surimi containing 1.5 to 3 per cent sodium citrate in addition to 3 per cent NaCl and 10 per cent sugar remains acceptable after 12 months' storage at −25°C (−13°F). Thus, sodium citrate seems to be effective in improving keeping quality of salted surimi.

Figs 1(a), 1(b) and 1(c) show the protective effect of sodium citrate on frozen surimi containing various amounts of sugar. The level of sodium citrate needed in salted surimi to maintain the minimum acceptability for practical use in making kamaboko (taste test score, 4.5), increases with a decrease in sugar content. The shelf life

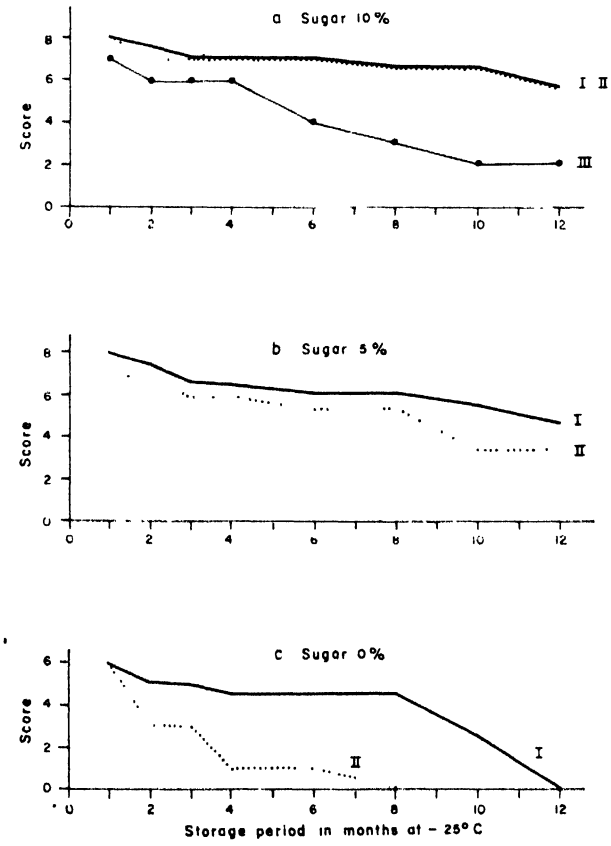


Fig 1. Changes in panel score for kamaboko forming ability of salted surimi during storage at −25°C

I ——— *Na-citrate 3 per cent*
II ····· *Na-citrate 1.5 per cent*
III ●——● *Na-citrate 0 per cent*

of frozen surimi containing no sugar is very poor even in the presence of sodium citrate. With 1.5 per cent sodium citrate, the shelf life of frozen surimi is less than two months. However, in the case of salted surimi with 5 per cent or 10 per cent sugar, the addition of 1.5 per cent sodium citrate gives excellent shelf life (eight and 12 months respectively). Thus, combinations of sugar and sodium citrate seem to show a significant improvement in the keeping quality of frozen salted surimi.

Effect of washing the comminuted fish flesh prior to use

Fig 2 shows the difference in the rate of acceptability between frozen surimi prepared with washed meat and that with unwashed meat. Both preparations contained the same additives, 3 per cent NaCl, 10 per cent sugar and

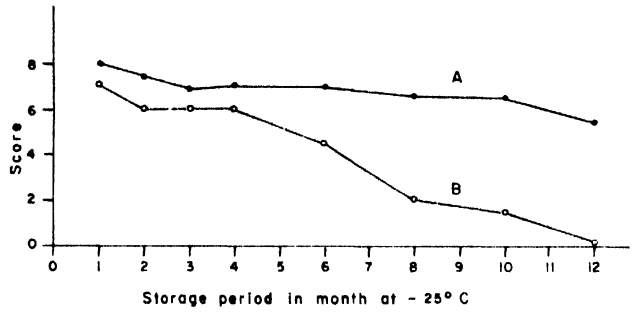


Fig 2. Changes in panel score for kamaboko forming ability of salted surimi prepared with washed and unwashed fish meat. A, *salted surimi prepared with washed meat;* B, *salted surimi prepared with unwashed meat*

3 per cent sodium citrate. The washed sample was acceptable after 12 months at −25°C (−13°F) and the unwashed remained acceptable for only four months.

It is concluded that the washing process of the fish meat is very important in preparing frozen surimi with good keeping quality.

Relationship between jelling and acceptability for kamaboko manufacture

The estimation of acceptable quality and the degree of jelling immediately after thawing was made during a 12-month storage period. A relationship between acceptability for kamaboko manufacture and the extent of jelling is shown in fig 3. As jelling increases it becomes

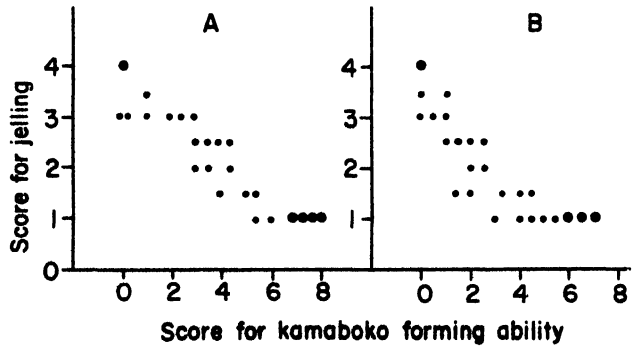


Fig 3. Relationship between the kamaboko forming ability and the extent of jelling of frozen surimi. A, *frozen surimi prepared with washed meat;* B, *frozen surimi prepared with unwashed meat*

less acceptable. Whenever surimi forms an elastic jell immediately after thawing (the score of jelling is above 3) only a brittle kamaboko of very poor quality is obtained. An elastic kamaboko of good quality results only when the thawed surimi is a sticky paste (the score of jelling is 1).

Jelling is caused by a formation of a network structure of myofibrillar proteins. It is impossible to regrind the jelled meat into a homogeneous sticky paste and to rebuild a strong network structure (an elastic kamaboko) by cooking. It appears that the prevention of jelling during cold storage could be an important key to the preparation of salted surimi with a good shelf life.

It is well known that sugar is effective in reducing the rate of jelling and this is the reason why as much as 10 per cent sugar is added to commercial salted surimi products (Ikeuchi and Simidu, 1963). However, the present study shows that sugar does not extend the shelf life longer than six months at −25°C (−13°F).

Migita and Okada (1963) recognized that the presence of lyotropic anions of alkali metal salts cause jelling of fish meat and showed that such anions as citrate or sulphate inhibit jelling caused by other salts like sodium chloride. The present study established that the combination of sugar and sodium citrate is very effective in improving the shelf life of salted surimi in the frozen state by reducing the jelling.

References

IKEUCHI, T and SIMIDU, W *Bull. Jap. Soc. scient. Fish.*, **29,** 1963 151, 157, 258.

MIGITA, M and OKADA, M *Bull. Tokai reg. Fish. Res. Lab.*, 1963 **36,** 21.

DISCUSSION

Danielsen (Switzerland): In his review paper, Kreuzer has touched on a very important point in his reference to the growth of the pelagic fishery. This fishery has increased at the rate of about 10 to 12 per cent per year over the past 10 years —as opposed to an annual increase of about 3 to 5 per cent for the demersal fishery. We must expect that pelagic fishing will continue to grow at about the same rate for some years, whilst the growth rate of the demersal fishery will decline.

I feel that it is shocking that in Peru 10 million tons a year of first class fish are turned into meal to feed poultry and meat animals to supply the overfed populations of Europe and North America. It should be the joint responsibility of governments to do the necessary research and development work so that the underfed people could benefit from the future growth of the fishery. The work of FAO should be appreciated in this regard.

Several countries have lately focused attention on fish protein concentrate (FPC). Very likely it will be possible, in the near future, to make a tasteless, odourless FPC flour of high nutritional value, which can be used as an ingredient of a number of foods. The papers of Okada and Tomiyama *et al.* are good examples of how cheap species of fish can be turned into specialities well accepted by consumers.

The fishing fleet is becoming more and more mobile, as witnessed particularly by the developments in Russia and Japan. The development of the purse-seine net has made it possible to take huge catches in a few hours. There is need for developing methods of preservation for use aboard the vessel, if such catches are to be turned into food for human consumption.

Our fishermen are very quantity-minded and their production is measured in terms of quantity, not quality. Remuneration systems should be designed to reward quality as well as quantity.

The processing of fish aboard the vessel presents difficulties. Freezer trawlers at first froze round fish, but later produced bone-in skin-off fillet blocks. Later again, pin bones were removed to produce boneless blocks which could be used directly for the manufacture of fish sticks and fish portions.

As the catches tend to get smaller and the freezer trawlers seek fish in more distant waters, the trips become longer. One way to increase the monetary yield of the vessel operation might be to increase the degree of processing on board and so make a better use of the capital and manpower resources. Rudolphi has mentioned the necessity of improving the shape of the blocks on German trawlers. No doubt this can be done. We shall also follow with great interest the development work being done towards the production of consumer pack IQF fillets and the like aboard the vessel.

Heen (Norway): I would like to comment on Danielsen's point concerning the role governmental institutions should play in product development, particularly perhaps in the use of those varieties which may provide food products for developing countries.

I fully agree that, in a competitive market, product development must be an integrated operation. The technical aspects are important, but other factors may be even more important than the discovery of a way in which a new product can be prepared. In my experience, most product development in government laboratories is futile. The products are rarely evaluated as to their likelihood of pleasing the taste of the consumers. Little consideration is given to the economic aspects and the retail price. Another difficulty relates to the fact that in developing areas you cannot very readily survey the housewives to find out whether they like such and such a product. I think a long-term study of people's habits and tradition in choosing and preparing food is required. This cannot be done by governmental institutions, except in countries where the government is also the producer and seller of products—in which case the government performs the same role as an integrated company. An integrated company which is both a producer and distributor has all the instruments, skills and financial tools to perform these functions. Studies in the various sciences and technologies are very helpful, but they are not the only decisive factors in successful product development.

Hansen (Denmark): I refer to the question raised by Danielsen, concerning the role of government institutions and private companies in product development. International institutions may be interested in this issue as was pointed out in Kreuzer's paper. If you will allow some generalization I can give the following picture of differences of purpose. The product development effort of FAO is directed towards the survival of mankind, while that of governmental institutions may concern the survival of the national fishery. Product development efforts of a company aim at the survival of the company. Some companies, however, have no equipment or experienced personnel for product development work. In such cases, governmental institutions may develop new products with the dual purpose of helping both the individual company and the local fishery. Examples of such development work are given in Aagaard's paper.

Bligh (Canada): I would like to comment briefly on experiences in Canada regarding the role of government in new product development.

There appears to be general agreement that the fishing industry is lagging behind other food industries in new product development. Much work is being done, for example, on the development of food products from seed proteins, some of which even simulate fish products. There is also growing concern over the diminishing catches of the more desirable or traditionally used species of fish. We must therefore pay more attention to product development from the under-utilized species. Harrison has stated that we must expect many changes in fish marketing between now and 1985. This again points out the need for more effort on new products.

With a few exceptions, the Canadian fishing industry is not equipped to carry out research and development work on new products. At the Freshwater Institute, we have endeavoured to develop new products and uses for some of the Canadian freshwater fish which have a low commercial value. A variety of excellent products have been prepared from these fish and the processing methods have been published. To generate interest in these products, we have distributed them to a large number of industrial and governmental agencies. They have received excellent ratings, but as yet none is being marketed. As the previous speakers have said, the introduction of a new product is very difficult and our experiences have shown that governments alone cannot do the job.

In our Great Lakes fishery, the lake trout, a choice species of fish, has become very much depleted and this caused a great deal of concern. However, the industry has now turned to other species of fish and has very successfully developed products and markets for smelt and perch.

In conclusion, I feel that government agencies in Canada have a definite role in the development of new fishery products, but they must have industrial encouragement and interest if they are to be successful.

Galliver (U.K.): Between them Sale and O'Sullivan have made what I think are three extraordinarily important points which this Conference would do well to take careful note of, namely:

(1) The consumer calls the tune, and any company that ignores this does so at its own peril, and is not likely to continue profitably in business. I think that, in developing countries, too little attention has been given to consumer needs and the acceptability of products.

(2) New product development must not be looked upon as an activity of technologists only. It involves the whole range of company activities. For example, Sale points out that in his company the product development team comprises technologists, marketing men and accountants. He also states that the whole board of his company takes part in new product development meetings, and I think that this emphasizes the importance of new product development in that company.

(3) New product development is difficult, as is illustrated by O'Sullivan's report that some 60 product ideas are, on average, necessary to produce one successful product on the market, and that 80 per cent of all new products launched in the United States fail.

The important thing for this meeting to note is that you must find out what the consumer wants, and then assemble the means of providing it. One of the things to assemble is the right raw material. In the case of vegetables, the producer uses specially bred and selected varieties, and carefully controls growing and harvesting conditions, in order to supply the processor with material tailored to his requirements. Similarly with meat, production has been directed specifically to meet the processors' needs.

In comparison, fishing is a crude hunting industry in which the processor has to accept the raw material presented to him,

and until quite recently has had little opportunity of influencing the catching industry. I think that it is inevitable that fish farming will assume increasing importance, until it reaches the point of supplying a reasonable proportion of our fish requirements. When this happens the catching industry will have to adapt itself rapidly to compete in producing the desired species in the right quality condition for processing.

Liston (U.S.A.): In marketing new products in developing countries, there is the problem of determining consumer acceptability in communities with little or no experience with the type of foodstuff which it is proposed to introduce. How can this be done? Must it be based on existing food habits? Can a market be created *de novo*? How significant are food taboos: do food habits change as industrialization proceeds? This type of problem is particularly acute in the case of products such as FPC.

I would suggest that the presentations by speakers in this session underscore the undesirability of treating processes such as freezing as methods for producing "better" fresh products. Frozen foods are manufactured products which should be marketed as such: not in competition with truly "fresh products".

Sale (U.K.): I would like to offer the following statistics in reply to Liston's question as to how new products are introduced to the housewife. The percentages of introduction are as follows:

In the shops	67 to 69 per cent
By friends and neighbours	17 to 22 „
TV advertising	2 to 9 „
Press advertising	5 to 7 „
Circular or coupon	2 „

Massa (Italy): The problems of introducing new fish products in developing countries are different from those which arise with the promotion of new products in developed countries. New food technologies must be envisaged and used in developing countries to process food for different applications. For example, radiation energy could be used to prolong the shelf life of fish products under cold storage and to sterilize animal products for quarantine purposes so as these products can be exported to developed countries.

Kreuzer (FAO): There is a need to make acceptability tests before introducing a new product on the market. These studies should be carried out on a large scale and, in the case of developing countries, there may be need of assistance through bilateral or international agreement. The technologists in developing countries will require particular training in order to give the problems of consumer preference and consumer acceptability, the attention they will require in future.

PART IV

THE QUALITY OF FROZEN FISH PRODUCTS AND ITS ASSESSMENT

FACTORS INFLUENCING QUALITY OF FROZEN FISH PRODUCTS

Factors Influencing Quality Changes During Frozen Storage and Distribution of Frozen Products, including Glazing, Coating and Packaging . *W. J. Dyer and J. Peters*

Changes in the Eating Quality of Frozen Stored Cod and Associated Chemical and Physical Changes *J. J. Connell*

Factors Affecting the Texture of Frozen Fish *Kirsteen O. Kelly*

Rate of Survival of Organisms of Sanitary Significance During Freezing and Subsequent Storage *A. Lekshmy, D. R. Choudhuri and V. K. Pillai*

Discussion

QUALITY ASSESSMENT

Quality Control of Frozen Fish in Modern Fish Industries *H. Jendrusch*

Evaluation of Quality of Frozen Fish and Fish Portions *U. Kietzmann*

A Taste Panel Technique for Evaluating the Eating Quality of Frozen Cod *C. R. Baines, J. J. Connell, D. M. Gibson, P. F. Howgate, Evelyn I. Livingston and J. M. Shewan*

Estimation of Hypoxanthine Concentrations in Fish Muscle by a Rapid, Visual Modification of the Enzymatic Assay Procedure *J. R. Burt, G. D. Stroud and N. R. Jines*

Objective Measurement of the Hardness Parameter in Cooked Fish Muscle . *A. H. Sutton and G. Main*

Use of Ultra-violet Light for Determining whether Fresh or Frozen Fish Has Passed Through *Rigor Mortis* *H. Wittfogel*

Discussion

Factors Influencing Quality Changes During Frozen Storage and Distribution of Frozen Products, Including Glazing, Coating and Packaging

by W. J. Dyer and J. Peters

Factors influencing quality changes during frozen storage and distribution of frozen products, including glazing, coating and packaging

Knowledge of time, temperature tolerance of many fishery products is reviewed, including some recent work on pollock (*Pollachius virens L.*) and haddock (*Melanogrammus aeglefinus L.*) fillets. It should be recognized that the quality of individual lots of the various species will vary considerably depending on initial quality, source, season and various biological factors, the type of packaging or glazing, temperature variations and humidity in the cold store, temperature history and fluctuation during marketing and distribution, and finally the method of cooking. Not only, then, must initial quality of the raw material and proper processing and preparation for storage of the frozen product be considered but, in practice, it is found that handling conditions during distribution to markets and interim holding as well as preparation of the cooked dish by the consumer equally, if not more significantly, determine final quality. Some data on glazing in alginate jellies, and on fillet blocks for further processing will also be discussed.

While chemical and physical changes in the proteins and in the lipids are primarily responsible for quality changes, these manifest themselves in terms of the eating quality of the cooked product, mainly in modification of the texture in the direction of decreased tenderness and of the development of undesirable flavours or odours. Recent research results are helping to clarify the way in which protein aggregation modifies the loss in moisture-holding capacity of the proteins and how this affects the texture changes of the cooked product. Progress is also being made in the role of lipid hydrolysis and oxidation in determining flavour and other changes. Likewise, electron microscopy is enabling identification of the changes in the fine structure of the muscle cells.

Facteurs influencant les changements de qualité au cours de l'entreposage frigorifique et de la distribution des produits congelés, notamment le glacage, le recouvrement et l'emballage

Le présent document passe en revue les connaissances actuelles sur la tolérance au temps et à la température de plusieurs produits des pêches et fait état de quelques récents travaux sur les filets de colin (*Pollachius virens L.*) et d'églefin (*Melanogrammus aeglefinus L.*). Il faut admettre que la qualité de chaque lot de différentes espèces varie dans une mesure considérable, en fonction de la qualité initiale, de l'origine, de la saison et de plusieurs facteurs biologiques, ainsi que du type d'emballage ou de glaçage, des variations de température et d'humidité dans la chambre froide, des températures successivement subies au cours des opérations de commercialisation et de distribution et finalement de la méthode de cuisson. Aussi faut-il considérer que non seulement la qualité initiale de la matière première, le traitement et la préparation en vue de l'entreposage du produit congelé sont des éléments essentiels de la qualité finale du produit, en pratique, la manipulation lors de la distribution aux marchés, ou encore la manutention temporaire et la cuisson par le consommateur, présentent une importance au moins égale. Quelques données sur la glaçage dans des gelées d'alginate et sur les blocs de filets destinés à un traitement ultérieur sont également discutées.

Les changements chimiques et physiques des protéines et des lipides qui sont les principaux responsables des altérations qualitatives affectent la comestibilité du produit cuit surtout par la modification de la texture, ce qui donne lieu à une diminution de la tendreté et à la manifestation de saveurs ou d'odeurs désagréables. Les résultats de recherces récentes ont contribué à éclaircir le processus par lequel l'agrégation des protéines modifie la perte de la capacité de rétention d'eau des protéines et comment cela affecte les changements de texture dans le produit cuit. Des progrès ont également été faits en ce qui concerne la connaissance du rôle joué par l'hydrolyse et l'oxydation des lipides dans la détermination de la saveur et d'autres changements. De même, la microscopie électronique permet l'identification des changements intervenant dans la fine structure des cellules musculaires.

Factores que influyen en los cambios de la calidad durante el almacenamiento congelado y distribución de los productos congelados incluyendo el glaseado, revestimiento y envasado

Se examinan los conocimientos actuales sobre el tiempo y la tolerancia a la temperatura de muchos productos pesqueros, incluyendo algunos recientes trabajos sobre los filetes de abadejo (*Pollachius sirens L.*) y eglefino (*Melanogrammus aeglefinus L.*). Debe reconocerse que la calidad de los lotes de las distintas especies variará considerablemente de acuerdo con la calidad inicial, procedencia, época y varios factores biológicos, con el tipo de envasado o glaseado, las variaciones de la temperatura y humedad en el frigorífico, los datos y fluctuaciones de la temperatura durante el mercadeo y la distribución, y, por último, según el método de preparación culinaria. No es sólo entonces cuando se debe considerar la calidad inicial de la materia prima y la elaboración y preparación adecuada para almacenar el producto congelado sino que, en la práctica, se puede observar que las condiciones de manipulación durante la distribución a los mercados y la conservación provisional, así como la preparación del plato cocinado por el consumidor, determinan igualmente, si no más sensiblemente, la calidad final del producto. Se examinarán también datos sobre el glaseado en gelatinas de alginato, y sobre los bloques de filetes para su elaboración ulterior.

Aunque los cambios de la calidad dependen principalmente de los cambios físicos y químicos en las proteínas y en los lípidos, aquéllos se manifiestan en la calidad comestible del producto cocinado, sobre todo en la modificación de la textura, en el sentido de que aumenta su dureza y surgen en ella sabores u olores indeseables. Los resultados de recientes investigaciones están ayudando a aclarar la manera en que la mezcla de las proteínas modifica la pérdida de capacidad de cada una de ellas para retener la humedad y en el modo en que esto influye en los cambios de textura del producto cocinado. También se está progresando en lo que se refiere a la función que desempeña la hidrólisis y la oxidación de los líquidos en el sabor y en otro cambios. Del mismo modo, el microscopio electrónico permite la identificación de los cambios y la delicada estructura de las células del tejido muscular.

WHILE freezing still remains the processing procedure (theoretically) capable of giving the consumer the best product marketable, the frozen food industry is not always successful in providing a first-class product. Our understanding of the basic principles involved in determining quality is progressing. While many of these have long been known, precisely how the various factors involved operate in practice under commercial conditions is only now becoming clear in many areas. Better definition of these factors controlling quality in its many aspects should enable us to improve quality and to see more clearly which areas need further study, both of the principles involved and of the actual application of those principles.

There appear to be four principal groups of factors each contributing to the quality of the product reaching the consumer's table:

(1) Quality of the initial raw material—its selection, processing, preparation and packaging.
(2) Freezing and storage conditions—rates of freezing, storage temperature, times, refreezing.
(3) Handling conditions during transportation to market areas, distribution, holding, retail outlets, etc.
(4) Preparation for cooking, including thawing and cooking methods.

Quality as evident in the eating quality of the cooked product is a composite of many factors: the initial condition of the individual fish used; the degree of glycolytic *post-mortem* autolysis and bacterial spoilage occuring prior to freezing; the changes attributable to cold storage deterioration (quite distinct in character); and finally, changes during thawing and on cooking.

Recent research has indicated new areas for examination of quality. For instance, the study of nucleotide degradation in cod and some other species has pointed out the probable contribution of inosine 5'-monophosphate (IMP) to flavour and possibly that of hypoxanthine (Hx) to a deleterious flavour (Kassemsarn *et al.*, 1963). The interaction of nucleotides with amino acids may strongly contribute to "meaty" or other flavours (Hashimoto, 1965). Hx may also have some merit as an indicator of deterioration (Jones *et al.*, 1964; Dyer *et al.*, 1966; Spinelli, Eklund and Miyauchi, 1964). The involvement of lipid hydrolysis and oxidation with protein stabilization has opened new vistas for understanding the role of lipid hydrolysis in deleterious changes in aggregation and denaturation of protein as it affects moisture-binding capacity and texture (Dyer and Fraser, 1959; Anderson, Steinberg and King, 1965; Hanson and Olley, 1965; King, 1966; Dyer, 1967a). Study of metal catalysed rancidity especially in its early stages in relation to fat oxidation and to the development of "seaweedy" and of "cold storage" flavours likewise is approaching the stage where some of its effects can be understood and perhaps avoided in the not too distant future (Castell, 1965; Marcuse, 1965). Recently (Kelly *et al.*, 1966; Cowie and Little, 1966) it has been shown that in cod pH may have an overriding effect on texture (low pH, less tenderness) and since pH can vary over rather wide limits due to the exercise and nutritional status of the fish at death it means that in special cases differences are marked; e.g. "rested" aquarium fish, gill netted cod, trap-caught heavily feeding cod (Newfoundland), fish frozen *pre-rigor* at sea. Seasonal differences in condition may also have a marked influence.

Presently there is a trend to utilization of new species and to preparation of new products from common species, a trend which seems likely to continue with our world shortage of high-quality protein foods. Already the differences in behaviour in the various species have led to increased understanding of the various factors involved in quality and acceptability and indeed in changing the food habits of various groups of consumers.

Not considered here are the factors affecting quality and storage life in cooked fish products, cooked prior to freezing and storage. The problems involved here are perhaps best known by our industrial confrères, there being very little published information available, but *see* Peters and Slavin (1962).

INITIAL QUALITY, PREPARATION AND PACKAGING

It is now widely recognized that "fish" is not a uniform material—size, sex, season, maturation, type of food, area, etc., all influence the characteristics of the flesh portion used for food. Such considerations are becoming more important as catching vessels range farther and farther afield, and seasonal effort becomes more spread out over the year. Different catching methods may greatly influence the degree of struggle at death; for instance the recent switch from harpooning to set-trawl lines for catching swordfish (*Xiphias gladius*) off the east coast of North America has greatly modified the flesh condition. Various workers have found large variations in the stores of high energy metabolic compounds in trawled fish due at least partly to variation in degree of struggle in the trawl on catching. About 1 in 12 trawled cod retained high levels of glycogen and high energy compounds (Bramstedt, 1952; Fraser, Weinstein and Dyer, 1965) which could result in marked differences in *post-mortem* pH and in texture and taste of the cooked product as already referred to above. Recently, more attention is being given to the effect on quality of methods of catching and of degree of struggle prior to death. Use of underwater television is helping to define the behaviour of trawl nets on the activity of the fish.

Emphasis is also being placed on the variation in composition and quality of the different parts of the flesh of fish; e.g. the red or brown muscle and in some species, the fatty layer present (Brandes and Dietrich, 1953; Fraser *et al.*, 1961, 1966; Bone, 1966).

Further evidence that chilled storage on ice prior to freezing tends to decrease frozen storage life has now been obtained (Peters, Cohen and King, 1963). The importance of adequate packaging in relation to prevention of loss of moisture vapour and of penetration of oxygen into the product is often overlooked. Perhaps it is necessary to demonstrate in a quantitative manner the actual losses in quality resulting in juxtaposition with the increased cost of the more effective packaging. Most scientific reports dealing with storage changes start off by stating they used packaging methods to avoid the problem of desiccation and oxidation, although some admit they may not have been entirely successful, as was mentioned in the paper on thaw-drip elsewhere at this Conference (Dyer, 1967b). Dehydration results in protein inextractability and irreversible denaturation (Duerr and Dyer, 1952) and of course oxidation of the lipid fraction results in flavour deterioration and may also deteriorate protein in addition.

Many organic films as well as laminates have been developed with varying degrees of permeability to water vapour and to oxygen and some have proven satisfactory for fish products (Ueno, 1962; Peters, 1964). Further, a considerable number of coatings, such as alginate gels, acetylated monoglyceride, and methoxy cellulose, all of which have application for specific products and conditions are also used. Some recent results with some of

TABLE 1. CHANGES IN WEIGHT OF HADDOCK DURING STORAGE*

Sample number and glaze		Index numbers of glazed haddock weights				
		Before glazing	*After glazing*	*After 6 weeks' storage*	*After 10 weeks' storage*	*After 20 weeks' storage*
1. Water	A	100.0	106.4	101.7	99.0	92.0
	B	(93.9)	(100.0)	(95.3)	(92.9)	(86.4)
2. Sodium alginate† medium viscosity 1.5 per cent	A	100.0	110.2	105.3	102.9	97.6
	B	(90.6)	(100.0)	(96.5)	(93.2)	(88.5)
3. Sodium alginate† low viscosity 3.0 per cent	A	100.0	112.2	106.3	103.5	98.4
	B	(89.1)	(100.0)	(94.9)	(92.3)	(87.5)
4. Carboxymethyl cellulose high viscosity 1.0 per cent	A	100.0	111.9	103.0	97.7	90.4
	B	(89.3)	(100.0)	(92.2)	(87.3)	(80.7)
5. Glucose 30 per cent, salt 10 per cent (by weight)	A	100.0	102.0	96.5	93.5	87.2
	B	(98.0)	(100.0)	(94.5)	(91.5)	(85.5)
6. Control, no glaze	A	100.0	—	97.4	95.8	92.8

* For ease in comparison of the various samples, the average weights of the fish have been converted to index numbers; in one set (line A) the weight of the fish before glazing equals 100 and in the other set (line B) the weight of the fish and glaze (after glazing) equals 100.

† Tri-calcium phosphate was added to the solution just prior to use to convert the alginate into the film forming calcium salt.

these products at the Gloucester Laboratory (Peters, unpublished data) are shown in table 1. Whole round haddock (*Melanogrammus aeglefinus L.*) were dipped in chilled (5°C, 41°F) solutions to give the percentage weight increases shown in table 1 and were then stored in a −18°C (0°F) cold room.

After the 20-week storage period two fish from each sample were thawed in cold running water, then filleted and skinned. Inspection of the round fish after thawing revealed that the eyes of the fish in each sample were very cloudy and sunken. The gills were found to be dark brown. The flesh, however, was firm to the touch. The flesh of all samples was darker than normal for the species and on the skin side was yellow in colour and had a rancid odour. One of the two fish from the glucose–salt glazed sample and one from the carboxymethyl–cellulose glazed sample were found to have dehydrated severely, particularly in the tail section.

The results of this glazing experiment indicate that the addition of the various materials tried does not give any improvement over a plain water glaze. In view of the difficulties involved in mixing the solutions and the expense of the materials used, it is evident that a plain water glaze renewed when necessary will give protection that is at least equal to that of the solutions tried in this experiment.

TIME AND TEMPERATURE OF STORAGE AND REFREEZING

This subject has frequently been reviewed (Dyer and Dingle, 1961; Lane, 1964; Connell, 1964). Some recent contributions on haddock and pollock (*Pollachius virens L.*) fillets (Ravesi *et al.*, 1967; Carver *et al.*, 1967) showed the marked dependence of storage life on storage temperature and on initial quality in these species. Haddock less than 24 h old were stored on ice and at intervals of one, three, nine and 15 days were filleted, packaged in 13½-lb (6.120-kg) waxed fillet block cartons and in 1-lb (0.454-kg) chipboard cartons and plate frozen. Storage temperatures and results of organoleptic assessment of the steamed product are shown in table 2. It would seem that there is a discrepancy in the results obtained for the one- and three-day iced haddock fillets stored at −18°C (0°F). On the other hand, taste panel scores indicated no consistent differences between the one- and three-day iced samples stored at −7°C (19.4°F) and −29°C (−20°F).

TABLE 2. FROZEN STORAGE LIFE OF HADDOCK FILLETS OF VARIOUS PRE-PROCESSING ICE STORAGE AGES AND FROZEN STORAGE TEMPERATURES

Storage temperature	*Storage life of haddock fillets (in weeks)* Days on ice			
	1 day	*3 days*	*9 days*	*15 days*
−7°C	8	7	3	0
−12°C	30	—	—	—
−18°C	37	46	25	1
−23°C	76	—	—	—
−29°C	86+*	86+*	32	1

* Indicates samples were still acceptable at this time but no further testing was possible because of the depleted stock.

The fillet blocks, stored at −18°C, were evaluated by taste tests conducted on fried, battered and breaded portions prepared just prior to testing. Portions from all but the 15-day iced blocks were still acceptable after 86 weeks of storage at −18°C. Test score averages indicate that portions made from one- and three-day iced blocks will have a considerable amount of storage life remaining after 86 weeks, but those prepared from nine-day iced fish were near the end of their storage life.

The results of similar experiments on pollock fillets are summarized in fig 1 showing the great increase in storage life as storage temperature is reduced. As expected, fillets from fish held one day in ice had the greatest stability in frozen storage. Unexpected, though, was the small difference in the storage stability of fillets from fish held between three and nine days on ice. In cod also no difference was found between one- and eight-day iced fish (Dyer and Fraser, 1959), but in other cases, freshness seems to exert a marked effect (reviewed by Dyer and Dingle, 1961).

The application of the time/temperature tolerance (TTT) estimates of quality deterioration developed by the USDA at Albany for frozen foods (Van Arsdel and Guadagni, 1959) has been discussed recently by Olsen, Guadagni, Jul and Dyer at the NATO Conference on

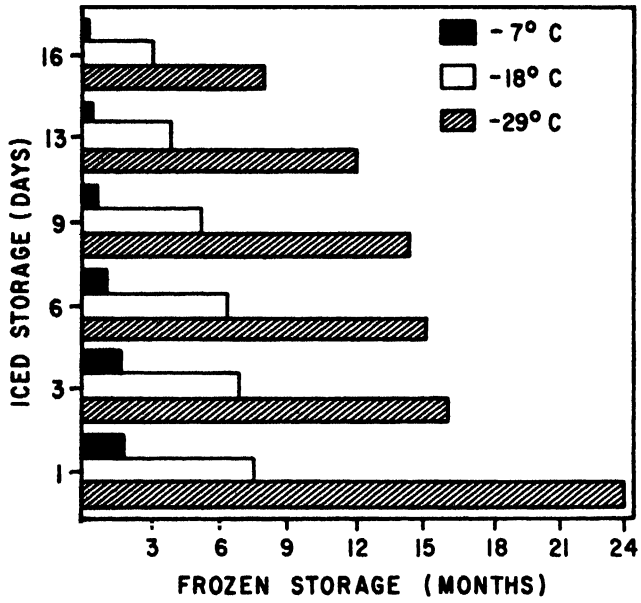


Fig 1. Summary of effect of iced storage time on frozen storage life of pollack fillets at various temperatures (Carver et al., *1967)*

Low Temperature Biology of Foods at Glasgow. While on the average, these curves are most useful in indicating effect on storage life and quality of various time/temperature experiences, the variations in quality of various lots of fish and even within the same lot should be given more attention. To this should be added consideration of the type and adequacy of packaging. Both these latter factors can considerably modify the rate of storage deterioration and it seems that an additional factor should be added to the TTT relationships to allow for this.

An additional factor is the delayed deterioration observed after temporary exposure of cod to temperatures of −12° to −9°C (10° to 15°F) for short periods (one to two weeks) (Dyer *et al.*, 1957; Dyer, Fraser and MacCallum, 1957). Deterioration as measured by taste panel tests and by changes in free fatty acid and in extractable protein was greater than expected from the exposure to high temperatures and most of the deterioration occurred in the storage period following return of the sample to the low temperature. As pointed out (Dyer, 1967a) this has not yet been confirmed on other species. However, additional evidence has been obtained from studies on refreezing (also reviewed by Dyer, 1967a). Most workers agree that thawing of frozen fish followed by processing and refreezing results in very little immediate change in quality. Even repeated freezing has little added effect (Lorentzen, 1965). However, when the refrozen pack was placed in frozen storage and tested at intervals, a rather rapid initial deterioration occurred (Dyer *et al.*, 1962); with Newfoundland trap cod this occurred within two months of refreezing at −23°C (−9°F) and at −18°C (0°F) as shown by greatly lowered taste panel scores and chemical changes. Additional experiments with trawler-caught offshore cod (Peters *et al.*, 1968) confirmed these findings, little change occurring on refreezing but a rapid development of free fatty acid occurred in the period between one week and two months of refrozen storage at −18°C (0°F), which correlated with a considerable drop in taste panel scores in the first month. It thus appears that the rise in temperature during thawing [or to −9°C (+16°F) in the previous experiments] together with refreezing has not resulted in any immediate damage; since there is little drop, if any, in scores immediately after refreezing. But some change has occurred which facilitates rapid deterioration during subsequent storage. As suggested previously (Dyer *et al.*, 1962) it now appears that this is due to liberation of various enzymes during the thawing or warming up. Membrane damage to cell membranes, lysosomes and microsomes or other cell particles allows diffusion of substrates and of enzymes and "activates" deteriorative reactions which can then proceed during storage (Dyer, 1967a). Such membrane damage is now commonly recognized (De Duve, 1959; Gould, 1965). Returning to the application of TTT data to storage life of frozen fish it seems that the "delayed" effect of this enzyme "activation" or liberation must be taken into account. However, more work with other species and conditions does seem necessary to determine the importance and limits of applicability of this factor. Its relevance to conditions during distribution are considered in the next section.

HANDLING CONDITIONS DURING DISTRIBUTION OF FROZEN FOODS

The cumulative effect of time/temperature experience determines the degree of quality loss by the time the frozen product reaches the consumer. If one adds to this the delayed effect on storage quality of thawing or temporary warming up then it becomes pertinent to enquire into the conditions met with by a product as it passes through the marketing chain. Although more difficult, the changes in quality should also be determined to measure the effect of the temperature and handling experiences on the product quality.

Much information is now available, especially on conditions although less is available on quality. Surveys of freezer storages or warehouses in the United States (Munter, Byrne and Dykstra, 1953; Lane, 1966) show generally temperatures of −18°C (0°F) or below. Railway refrigerator cars are usually much higher (Taylor and Harrison, 1948) as are refrigerated trucks (Lentz and Rooke, 1961; Lentz, Rooke and Foley, 1961). Surveys of conditions in the U.S. industry (Lane, 1966) indicate similar wide variations in conditions. Only 9 per cent had mean trip temperatures of −18°C (0°F) or better, and 51 per cent were fair between −18°C (0°F) and −12°C (+17.6°F), the rest being higher. Conditions in retail cabinets were also often poor, although many were excellent. British surveys show essentially similar results with some improvement between 1959 and 1965 (Anon, 1966). A very complete survey by Lorentzen (1963) in Norway is in remarkable agreement with the other data available. Calculations of TTT accumulated degradation due to this average temperature experience does not indicate that quality loss would be excessive (Jul, 1963) even with transport at quite high temperatures for short periods. However, insufficient data is presently available on the rate of quality loss at various temperatures in fishery products and none is available in the case of many others (Jul, 1963; Lane, 1966). Neither has information been obtained as yet of the significance of

the delayed temperature effect (discussed above) on quality deterioration where the product remains in the retail cabinet or in the consumer's home freezer for a few weeks or more.

Attempts to improve transport temperatures have met with some success, e.g. the publicizing of the AFDOUS code in the United States [temperatures not to exceed −18°C (0°F)]. The fact that a good proportion of the conditions in the retail chain are good indicates that the equipment can be operated satisfactorily in most cases. Further study of shortcomings and especially emphasis on maintenance of proper low temperatures to all handling and operating personnel appears necessary. The question arises, though, whether we have enough convincing data on the relationship of temperature changes and quality in specific products. Surveys of product quality are few indeed and the authors do not know of any work where a frozen fishery product has been quality tested as it passed through commercial channels. About the only data available are the U.S. Consumer Reports surveys of market quality of frozen fish sticks (Feb. 1961); frozen shrimp (Sept. 1961) and frozen fish fillets (Anon., 1963), in which the quality of the frozen fishery products tested was described as "dismal". Only one of 26 items rated Grade A and nearly half (46 per cent) were substandard. Initial quality and packing defects accounted for some of the deficiencies in quality but "by far the most common cause of quality loss, however, was deterioration attributable to overlong storage or storage at temperatures ranging above the desirable level of −18°C (0°F). It seems that the retail quality of frozen fish leaves something to be desired and of course is in line with the lower price tag usual on the American continent for frozen as compared to "fresh" fish.

PREPARATION FOR COOKING AND COOKING METHODS

While a good deal of work is proceeding on thawing of frozen fish for further processing (reviewed elsewhere at this Conference), surprisingly little has been done on thawing prior to cooking or to preparation for cooking, or on possible quality changes occurring during this operation. Apart from the thaw-drip which is an obvious disadvantage of thawing, little is known. In some areas, it is becoming common (Anon., 1963) to thaw frozen packs prior to sale and to retail them as fresh fish, often without any labelling information to indicate that thawed fish are involved. One recent report (Anon., 1966) indicates that the spoilage rate of fillets cut from thawed cod may be somewhat slower than unfrozen fillets, at least in the earlier period.

Cooking method can also influence the acceptability of the product (Carver and Steinberg, 1959; Dyer *et al.*, 1964). With a good quality fish, any cooking method may be used but frying does mask some of the off-flavour and poor texture characteristic of poor quality material. It was also found at least with cod that the taste and texture characteristics of frozen storage quality loss are much more easily detected and are more objectionable to the taste than the early stages of spoilage in the product prior to freezing (Dyer, 1964).

References

ANDERSON, M L, STEINBERG, M A and KING, F J In *The Technology of Fish Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 105. 1965

ANON. Frozen fish fillets. *Consumer Reports*, 30th January. 1963

ANON. *Torry Research Station Annual Report* (1965), Aberdeen, 63 pp. 1966

BONE, Q *J. mar. biol. Ass. U.K.*, **46**, 321. 1966

BRAMSTEDT, F *Fette Seifen AnstrMittel*, **64**, 820. 1962

BRANDES, C H and DIETRICH, R *Ibid.*, **55**, 533. 1953

CARVER, J H and STEINBERG, M A *Comml Fish. Rev.*, **21**(10), 1. 1959

CARVER, J H, *et al.* (MS.) 1967

CASTELL, C H In *The Technology of Fish Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 98. 1965

CONNELL, J J In *Proteins and Their Reactions*, ed. H. W. Schultz and A. F. Anglemeir, The AVI Publ. Co., Westport, Conn., chapter 12, p. 255. 1964

COWIE, W P and LITTLE, W T *J. Fd Technol.*, **1**, 335. 1966

DE DUVE, C In *Subcellular Particles*, ed. T. Hayashi, Ronald, New York, p. 128. 1959

DUERR, J D and DYER, W J *J. Fish. Res. Bd Can.*, **8**, 325. 1952

DYER, W J *ASHRAE Jl*, **6**, 40. 1964

DYER, W J Deterioration and storage life of frozen fish. *Recent Advances in Food Science*, **4**. (MS.) 1967a

DYER, W J Effect of brining and polyphosphate on yield and quality. FAO Technical Conference on the Freezing and Irradiation of Fish, 4th–8th September, Madrid. 1967b

DYER, W J and DINGLE, J R In *Fish as Food*, ed. G. Borgstrøm, Academic Press, New York, chapter 9, p. 275. 1961

DYER, W J and FRASER, D I *J. Fish. Res. Bd Can.*, **16**, 43. 1959

DYER, W J, FRASER, D I and LOHNES, D *Ibid.*, **23**, 1821. 1966

DYER, W J, FRASER, D I and MACCALLUM, W A *Ibid.*, **14**, 925. 1957

DYER, W J, FRASER, D I, ELLIS, D G and MACCALLUM, W A *Ibid.*, **14**, 627. 1957

DYER, W J, FRASER, D I, MACINTOSH, R G and MYER, M *J. Fish. Res. Bd Can.*, **21**, 577. 1964

DYER, W J, FRASER, D I, ELLIS, D G, IDLER, D R, MAC-
1962 CALLUM, W A and LAISHLEY, E *Annex 1962–1 Bull. int. Inst. Refrig.*, p. 515.

FRASER, D I, DYER, W J, WEINSTEIN, H M, DINGLE, J R and
1966 HINES, J A *Can. J. Biochem. Physiol.*, **44**, 1015.

FRASER, D I, MANNAN, A and DYER, W J *J. Fish. Res. Bd*
1961 *Can.*, **18**, 893.

FRASER, D I, WEINSTEIN, H M and DYER, W J *Ibid.*, **22**, 83.
1965

GOULD, EDITH *Testing the Freshness of Frozen Fish*, Fishing
1965 News (Books) Ltd., London, 51 pp.

HANSON, S W F and OLLEY, J In *The Technology of Fish*
1965 *Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 111.

HASHIMOTO, Y In *The Technology of Fish Utilization*, ed.
1965 R. Kreuzer, Fishing News (Books) Ltd., London, p. 57.

JONES, N R, MURRAY, J, LIVINGSTON, E I and MURRAY, C K
1964 *J. Sci. Fd Agric.*, **15**, 763.

JUL, M *Fd Technol., Champaign*, **17**, 1000.
1963

KASSEMSARN, B, PEREZ, B, MURRAY, J and JONES, N R
1963 *J. Fd Sci.*, **28**, 28.

KELLY, K, JONES, N R, LOVE, R M and OLLEY, J *J. Fd*
1966 *Technol.*, **1**, 9.

KING, F J *J. Fd Sci.*, **31**, 649.
1966

LANE, J P *Fd Technol., Champaign*, **18**, 1100.
1964

LANE, J P *Ibid.*, **20**, 197.
1966

LENTZ, C P and ROOKE, E A *Food in Canada*, **21**(12), 38.
1961

LENTZ, C P, ROOKE, G A and FOLEY, M A *Ibid.*, May, p. 24.
1961

LORENTZEN, G F *J. Refrig.*, **6**(4), 76.
1963

LORENTZEN, G *Kulde*, **19**(4), 53.
1965

MARCUSE, R In *The Technology of Fish Utilization*, ed.
1965 R. Kreuzer, Fishing News (Books) Ltd., London, p. 261.

MUNTER, A M, BYRNE, C H and DYKSTRA, K G *Fd Technol.*,
1953 *Champaign*, **7**, 356.

PETERS, J A *ASHRAE Jl*, **6**(8), 72.
1964

PETERS, J A, COHEN, E H and KING, F J *Fd Technol., Cham-*
1963 *paign*, **17**, 787.

PETERS, J A, MACCALLUM, W A, DYER, W J, IDLER, D R,
1968 SLAVIN, J, LANE, J P, FRASER, D I and LAISHLEY, E *J. Fish. Res. Bd Can.*, **25**(2), 299–320.

PETERS, J A and SLAVIN, J W *Annex 1962–1 Bull. int. Inst.*
1962 *Refrig.*

RAVESI, ELINOR, *et al.* (MS.)
1967

SPINELLI, J, EKLUND, M and MIYAUCHI, D *J. Fd Sci.*, **29**, 710.
1964

TAYLOR, D H and HARRISON, J S M *Prog. Rep. Pacif. Cst Stns*,
1948 **74**, 23.

UENO, S *J. Fd hyg. Soc. Japan*, **3**(3), 1.
1962

VAN ARSDEL, W B and GUADAGNI, D G *Fd Technol.*,
1959 *Champaign*, **13**, 14.

Changes in the Eating Quality of Frozen Stored Cod and Associated Chemical and Physical Changes

by J. J. Connell

Changes in the eating quality of frozen stored cod and associated chemical and physical changes

Fillets obtained from whole gutted cod (*Gadus callarias*) held in melting ice for periods of up to 17 days have been frozen under standard conditions, wrapped to prevent desiccation and stored at steady temperatures of −14°, −22° and −29°C (+7°, −7° and −20°F). After thawing in still air under standard conditions the eating quality of the fillets was evaluated by the new taste panel technique described elsewhere in this Conference. In addition, the following objective tests were carried out on the thawed, uncooked fillets; trimethylamine, hypoxanthine, colour index (blue-purple colour with concentrated acid), pH, protein extractability and cell fragility.

After a relatively small initial change, the taste panel freshness scores of the fish held at −14°C (+7°F) remained virtually constant even though the samples had undergone a considerable degree of cold storage deterioration. On the other hand cold storage flavour (and odour) and texture scores showed a rapid initial increase which gradually tailed off. However these changes cannot be adequately represented in an exponential form. At lower temperatures of storage, the rates of cold storage change were correspondingly reduced. Trimethylamine and hypoxanthine concentrations did not change much during frozen storage, and can therefore be used as indices of pre-freezing quality.

The correlation between protein extractability, cell fragility or colour index and cold storage texture or flavour scores were obtained; the usefulness of these tests as objective measures of cold storage deterioration will be discussed.

Changements affectant la qualité à la consommation de la morue congelée entreposée et changements physiques et chimiques associés

Des filets obtenus à partir de morue entière (*Gadus callarias*) éviscérée maintenue dans la glace en fusion pendant des périodes jusqu'à 17 jours ont été congelés sous des conditions normales, mis sous enveloppe pour prévenir la dessiccation et entreposés à des températures constantes de −14°, −22° et −29°C (+7°, −7° et −20°F). Après décongélation à l'air sous des conditions normales la qualité des filets à la consommation a été évaluée au moyen d'une nouvelle technique de dégustation décrite dans un autre document présenté à cette conférence. Les essais objectifs suivants ont été en gutre effectués sur les filets décongelés et crus: triméthylamine, hypoxanthine, indice de couleur (couleur bleu-pourpre avec acide concentré), pH, extractibilité des protéines et fragilité cellulaire.

Après un changement initial relativement faible, les notes de fraîcheur données par le jury de dégustation pour le poisson maintenu à −14°C (+7°F) sont restées pratiquement constantes, bien que les échantillons aient subi un degré considérable de détérioration pendant l'entreposage. D'autre part les notes relatives au goût typique de l'entreposage frigorifique (et à l'odeur) ont montré une rapide augmentation initiale puis une diminution graduelle aboutissant à une disparition complète. Cependant ces changements ne sauraient être représentés d'une manière adéquate sous une forme exponentielle. A de plus basses températures d'entreposage, la vitesse à laquelle se manifestent les changements dûs à l'entreposage frigorifique avait proportionnellement diminué. Les concentrations de triméthylamine et d'hypoxanthine n'ont pas subi de changements notables au cours de l'entreposage à l'état congelé et peuvent par conséquent servir d'indices de la qualité antérieure à la congélation.

La corrélation a été établie entre l'extractibilité de la protéine, la fragilité cellulaire ou l'indice de couleur et les notes de texture ou de goût après l'entreposage frigorifique. L'utilité de ces essais en tant que mesures objectives de la détérioration due à l'entreposage frigorifique fera l'objet d'une discussion.

Cambios en la calidad comestible del bacalao almacenado congelado y consiguientes modificaciones químicas y físicas

Los filetes obtenidos de bacalao entero destripado (*Gadus callarias*) conservado en hielo fundente durante períodos de hasta 17 días, se han congelado en condiciones normales, se han recubierto para evitar la desecación y se han almacenado a temperaturas constantes de −14°, −22° y −29°C (+7°, −7° y −20°F). Después de descongelarlos en aire inmóvil en condiciones normales se evaluó la calidad comestible de los filetes con la nueva técnica de equipo de catadores descrita en otra parte en esta Conferencia. Además, se realizaron las pruebas objetivas siguientes con los filetes descongelados y sin cocinar: trimetilamina, hipoxantina, índice de color (azul-púrpura con ácido concentrado), pH, extractabilidad de las proteínas y fragilidad de las células.

Después de un cambio inicial relativamente pequeño, las puntuaciones del equipo de catadores sobre la frescura del pescado mantenido a −14°C (+7°F) se mantuvieron prácticamente constantes a pesar de que las muestras sufrieron un considerable grado de deterioración durante su almacenamiento en frío. Por otro lado, las puntuaciones del sabor (y olor) y las de la textura en el almacenamiento en frío, indicaron un rápido incremento inicial que disminuyó gradualmente. Sin embargo, estos cambios no se pueden representar adecuadamente en forma exponencial. A inferiores temperaturas de almacenamiento, se redujeron correspondientemente los ritmos del cambio en el almacenamiento en frío. Las concentraciones de trimetilamina e hipoxantina no variaron mucho durante el almacenamiento en congelación, y por esto se pueden usar como índices de la calidad antes de la congelación.

Se obtuvo la correlación entre la extractabilidad de las proteínas, la fragilidad de las células o el índice del color y las puntuaciones correspondientes a la textura y el sabor en el almacenamiento en frío; se examinará la utilidad de estas pruebas como medidas objetivas de la alteración debida al almacenamiento en frío.

THE final eating quality of frozen stored fish depends on all the deteriorations ensuing between the death of the fish and cooking it. In the case of most frozen fish at present marketed these deteriorations are concentrated in the stages before freezing, that is the normal "wet" spoilage of the fish, and during storage in the frozen state. A good deal is known about changes in the eating quality of spoiling unfrozen fish, and somewhat less about similar changes in frozen stored fish of good initial quality, but little systematic work has been done on following the changes in quality of frozen stored fish of differing initial degrees of spoilage. Lane (1964) has reviewed a few references dealing with this topic, and Dyer *et al.* (1964) have assessed the palatability of frozen cod fillets having three initial grades of quality.

The present work is part of a systematic study of the quality changes in several species of fish of different initial degrees of spoilage which are then stored under several different conditions of frozen storage. Both organoleptic and a number of well-established objective

methods of quality evaluation are being tried in order to find those that are of most utility. This paper describes results on frozen cod fillets which have been cut from whole, gutted fish of different degrees of spoilage.

EXPERIMENTAL

Material

North Sea cod (*Gadus callarias*) caught throughout the period June 1965 to August 1966 were gutted at sea and immediately packed in melting ice for periods of two, five, eight, 14 and 17 days. After these periods, the fish were filleted, frozen in an air-blast at −34°C (−30°F), closely wrapped in threes in aluminium foil to prevent desiccation, and stored at temperatures of −14°, −22° and −29°C (+7°, −7° and −20°F). After storage periods ranging from a few days to a year, the fillets were thawed by leaving them in still air at 1.5°C (35°F) overnight.

Organoleptic methods

The taste panel technique described elsewhere at this Conference (Baines *et al.*, 1967) was employed, the same eight trained tasters being used throughout. Samples cut from the mid-portions of the fillets were used for cooking and tasting; either one or two fillets of each icing, temperature of storage and period of frozen storage, were taken for tasting. In all, the numbers of fillets tasted which were held at −14°C, −22°C and −29°C were about 140, 70 and 70 respectively.

Objective methods

The objective methods used were selected on the basis that they either had reached an advanced state of development as tests of quality or were of particular relevance to quality assessment of frozen fish. The methods used were determinations of trimethylamine, hypoxanthine, cell fragility, protein extractability, pH and blue-purple colour formed on addition of sulphuric acid (the so-called colour ratio test). The first two of these methods are particularly valuable in assessing the quality of spoiling unfrozen fish, the second two have been used as indices of quality deterioration in frozen fish with particular reference to textural changes, whilst the last method also appears to be related to quality deterioration in frozen cod.

Samples for trimethylamine, hypoxanthine, pH and colour ratio were obtained from the thawed fillets by cutting off portions about ½ in wide immediately adjacent at the head and tail end to the centre portion removed for tasting; these portions were then cut into pieces which were well mixed. Connective tissue-free samples for cell fragility and protein extractability were taken from the remaining head portion of the fillet according to the procedure of Love and MacKay (1962).

Perchloric acid extracts for trimethylamine and hypoxanthine determinations were obtained by the method of Jones *et al.* (1964), trimethylamine and hypoxanthine being determined on unneutralized and neutralized extracts respectively. Trimethylamine and hypoxanthine were determined automatically by the procedures of Murray and Burt (1964) and Jones, Murray and Burt (1965) respectively. Protein extractability and cell fragility were determined according to Ironside and Love (1958) and Love and MacKay (1962). For pH determinations by means of the glass electrode 50 g muscle were blended in 100 ml cold water, and this mixture was subsequently diluted with cold water to the correct muscle/water ratio for determining the colour ratio with sulphuric acid by the method of Connell (1966).

RESULTS AND DISCUSSION

This experiment provided a considerable amount of data, and numerous correlations between the various parameters can be calculated; it is not possible within the space of this paper to present all this material, therefore only a selection of the main findings will be given.

Changes in taste panel freshness flavour scores during frozen storage at the three different temperatures are shown in fig 1. This data was analysed to see whether there was any dependence of score on time of storage in the frozen state. This analysis (shown in table 1, which gives the mean scores for all the treatments) revealed that in only three of the 15 treatments was there a significant dependence of score on storage time. Thus in almost all cases the flavour characteristics of cod of various degrees of spoilage are unaffected by the conditions of frozen storage employed in this experiment. This result should be compared to that of Ehrenberg and Shewan (1959) who found that at a storage temperature of −30°C (−22°F), the flavour scores of cod stored for up to 23 days in ice before decreased slightly on average over a period of about a year. It was also found that the scores of initially fresher fish decreased during frozen storage at this temperature, whilst the scores of initially staler fish tended to increase. The indications with the present results are that where slight changes in flavour scores do occur with time of storage in the frozen state, they follow the pattern of Ehrenberg and Shewan's results. Table 1 also shows the mean freshness flavour scores of unfrozen cod of various degrees of spoilage tasted by the panel at approximately the same time as they were tasting the frozen samples. The flavour scores of the unfrozen and frozen samples stored for eight or more days in ice

TABLE 1. MEAN FRESHNESS FLAVOUR SCORES OF COD OF DIFFERENT INITIAL FRESHNESS HELD AT DIFFERENT TEMPERATURES OF STORAGE IN THE FROZEN STATE

Days in ice	*Storage temperature* −14°C +7°F	−22°C −7°F	−29°C −20°F	*Unfrozen**
2	6.64 (0.09)	7.29† (0.11)	7.16 (0.20)	7.90
5	6.51 (0.13)	6.98‡ (0.12)	7.02 (0.20)	7.20
8	6.51 (0.12)	6.75 (0.11)	6.73 (0.15)	6.40
14	4.78 (0.13)	4.50 (0.20)	5.12 (0.20)	4.80
17	4.03 (0.28)	3.75 (0.17)	3.43§ (0.33)	4.00

The values in brackets are the standard errors of the means.

* Mean values taken from a separate experiment.

† The values for this condition of storage show a significant regression of −0.018 score units/week of frozen storage. Extrapolated value at zero weeks of storage is 7.94.

‡ The values show a significant regression of −0.016 score units/week of frozen storage. Extrapolated value at zero weeks of storage is 7.49.

§ The values show a significant regression of +0.068 score units/week of frozen storage. Extrapolated value at zero weeks of storage is 2.10.

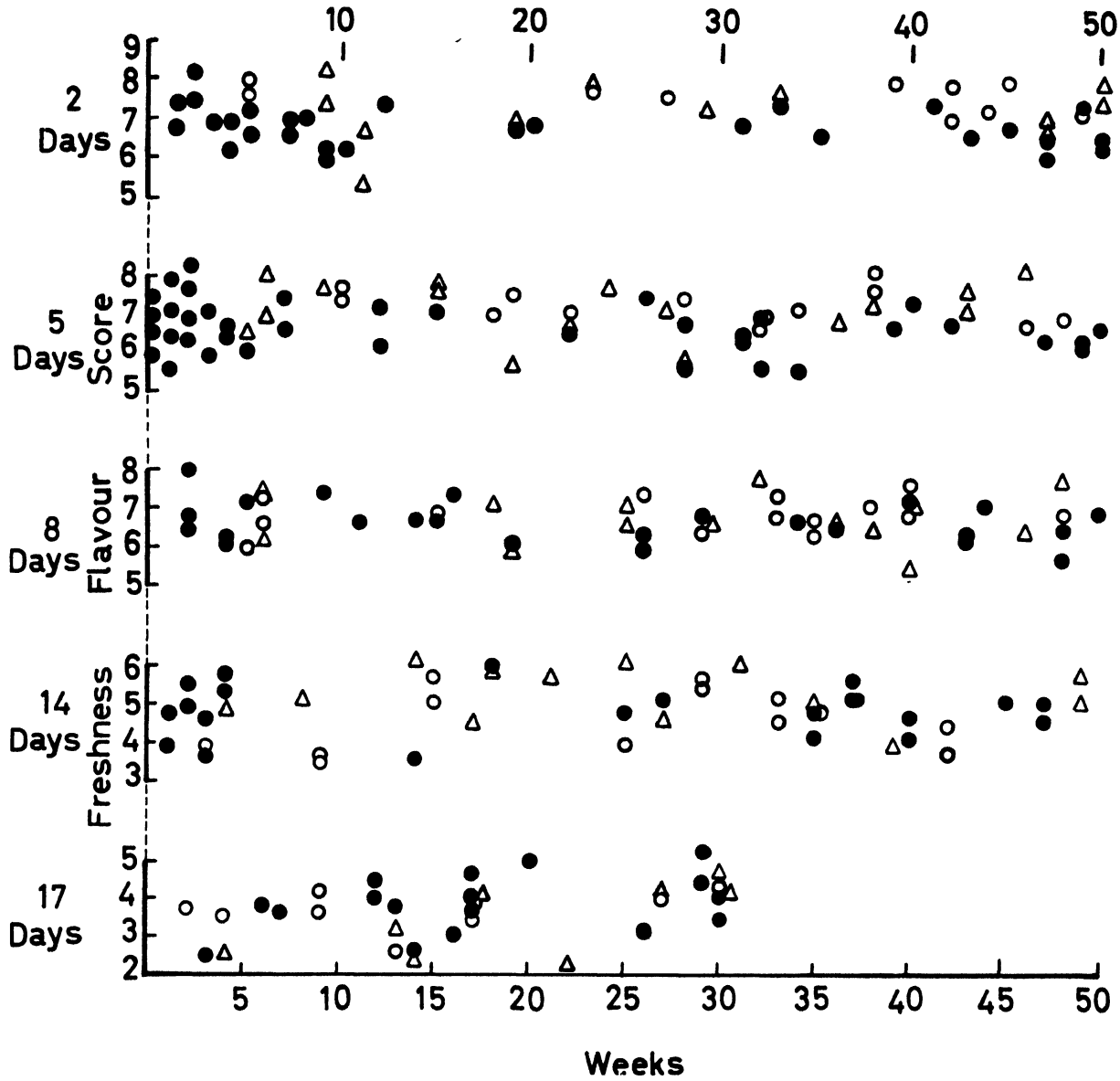


Fig 1. Changes in freshness flavour scores in cod of different initial freshness held at different temperatures of storage in the frozen state. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

do not differ, and it is therefore concluded that for fish of this kind, freezing and frozen storage has little effect on freshness flavour scores. It has been shown in a separate, direct comparison of unfrozen and frozen and immediately thawed cod of three or more days in ice, that freezing of itself has no effect on the freshness flavour score. The mean freshness flavour scores of the frozen and stored two and five days iced fish are significantly lower than those of the unfrozen fish (table 1), which presumably means that there is a small, rapid initial fall in score during frozen storage, particularly at −14°C.

Regardless of the degree of frozen storage deterioration, the panel is in all cases able to discriminate satisfactorily between fish which have been iced for eight days or more. Where the amount of frozen storage deterioration is relatively small, as for example during storage at −22° and −29°C, the panel is sometimes able to discriminate between cod which have been stored for two, five and eight days. However, where the amount of frozen storage deterioration is large, for example during storage at −14°C, the panel is not able to discriminate between the fresher samples of cod. This is because the subtle flavour differences existing between the freshest samples of cod are either eliminated under conditions of poor frozen storage or masked by overlying cold storage flavours.

The trimethylamine content has been used very considerably as an objective measure of the freshness of unfrozen cod (Farber, 1965; Gould, 1965), but the hypoxanthine content appears to offer some advantages for this purpose. It has been found in the present work that both the trimethylamine and hypoxanthine contents of cod of any of the degrees of freshness tested do not change significantly with time of storage at −14°, −22° or −29°C. This is a useful result in that it opens up the possibility of using these chemical methods as indices of initial freshness before freezing which are free of the effects of frozen storage. There appears to be some con-

flict of opinion as to whether the trimethylamine content changes during frozen storage, though no previous results on the present scale have been published (Banks, 1962). As far as changes in the concentration of hypoxanthine during frozen storage are concerned, a limited number of observations (Jones, 1963) indicated that a slight increase occurred over 60 weeks during storage at −14°C, but not at lower temperatures. The discrepancy with the present results may be accounted for by the fact that Jones (1963) employed cod which were in an essentially different biochemical state, namely a single, uniform batch of *pre-rigor* frozen fish.

The mean values of trimethylamine and hypoxanthine contents at the three temperatures of storage are shown in table 2. The differences in the amounts of these two substances in the frozen cod of different initial freshness closely parallel the changes occurring in spoiling, unfrozen North Sea cod (Jones *et al.*, 1964). The average hypoxanthine concentrations of samples stored at all temperatures plotted in a logarithmic form are almost exactly linearly related to the period of initial storage in ice (fig 2), whilst the corresponding concentrations of trimethylamine are linear only for the period from five days onwards (fig 3). In other words, there is a delay of about five days before the concentration of trimethylamine starts to increase, whereas the concentration of hypoxanthine increases from the commencement of iced storage. In addition, there is more variation in the trimethylamine concentrations for any given treatment than there is in hypoxanthine concentrations, the coefficient of variation (standard error of mean value/mean) for trimethylamine being twice that for hypoxanthine. It is therefore evident that for North Sea cod frozen and stored under these conditions, a measurement of the hypoxanthine concentration is a better predictor of the initial period of storage in ice than a measurement of trimethylamine concentration. Flavour scores of unfrozen North Sea cod are related to the period of storage in ice, and in so far as these scores can be said to indicate the freshness of the cod, it can be said therefore that hypoxanthine is a better indicator of the initial freshness of frozen cod than is trimethylamine. As the freshness flavour scores of frozen cod of eight days or more in ice are not significantly different from those of unfrozen cod of the same age in ice, hypoxanthine determinations can be used to predict the freshness flavour scores of frozen cod of this degree of spoilage. However, for fish stored for two or five days in ice hypoxanthine determinations will give a prediction of freshness flavour score for frozen cod which is higher than the actual score, especially where the fish have been frozen stored at a high temperature.

Changes in cold storage flavour with storage time are shown in fig 4. In the case of cod stored initially for two,

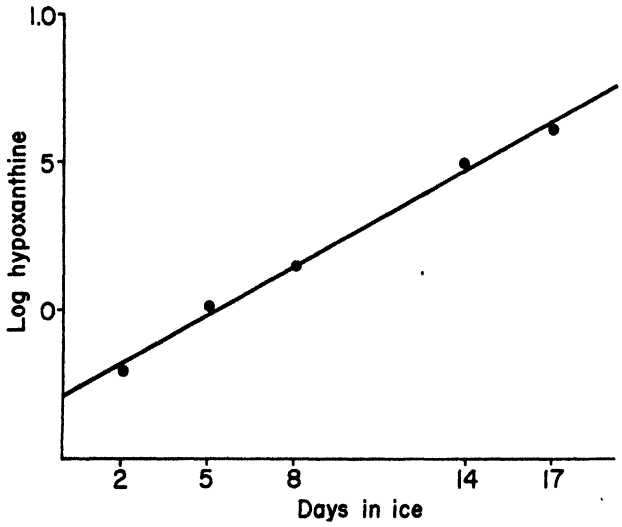


Fig 2. Mean hypoxanthine concentrations in cod of different initial freshness held at temperatures of −14°C, −22°C and −29°C for up to 50 weeks. The hypoxanthine concentrations are averaged over all the temperatures of frozen storage

TABLE 2. MEAN TRIMETHYLAMINE AND HYPOXANTHINE CONCENTRATIONS IN COD OF DIFFERENT INITIAL FRESHNESS HELD AT DIFFERENT TEMPERATURES OF STORAGE IN THE FROZEN STATE

(a) Trimethylamine (mg/100 g flesh)

Days in ice	Storage temperature −14°C +7°F	−22°C −7°F	−29°C −20°F	Mean value for all temperatures of storage	Log mean value
2	1.74	1.89	1.81	1.79 (0.17)	0.25
5	2.00	1.58	2.14	1.91 (0.22)	0.28
8	4.77	3.65	3.51	4.06 (0.63)	0.61
14	26.57	34.63	21.95	27.82 (2.13)	1.44
17	45.73	51.47	52.59	48.86 (3.45)	1.69

The values in brackets are the standard errors of the means.

(b) Hypoxanthine (μmoles/g flesh)

Days in ice	Storage temperature −14°C +7°F	−22°C −7°F	−29°C −20°F	Mean value for all temperatures of storage	Log mean value
2	0.65	0.57	0.57	0.61 (0.04)	−0.21
5	1.11	0.96	0.95	1.02 (0.03)	0.01
8	1.50	1.34	1.31	1.40 (0.06)	0.14
14	3.08	3.19	2.63	3.00 (0.14)	0.48
17	3.75	4.33	4.41	4.06 (0.20)	0.61

The values in brackets are the standard errors of the means.

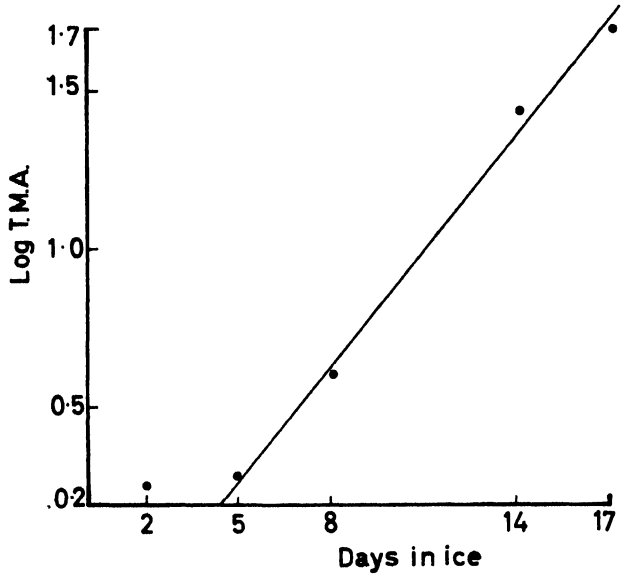


Fig 3. Mean trimethylamine concentrations in cod of different initial freshness held at temperatures of −14°C, −22°C and −29°C for up to 50 weeks. The trimethylamine concentrations are averaged over all the temperatures of frozen storage

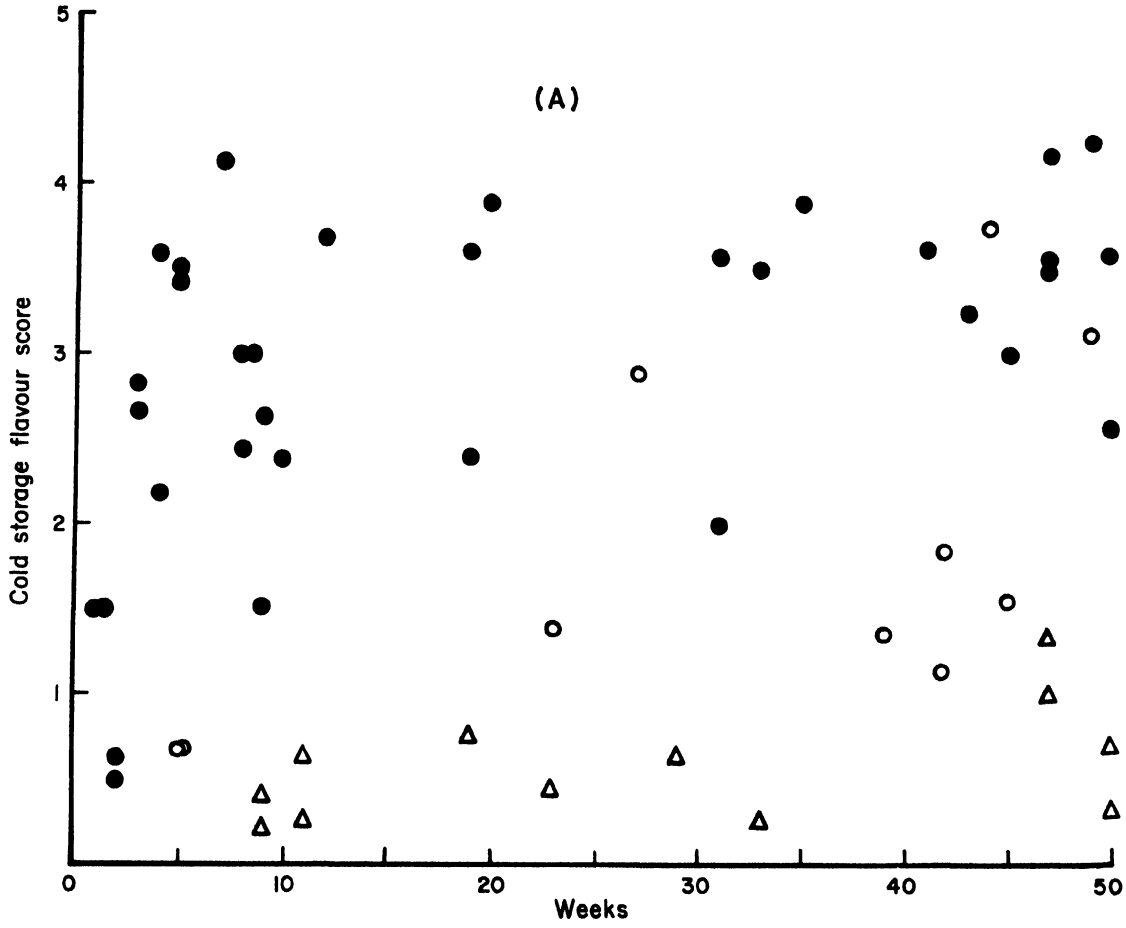


Fig 4(a). Changes in cold storage flavour scores in cod of different initial freshness held at different temperatures of storage in the frozen state, two days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

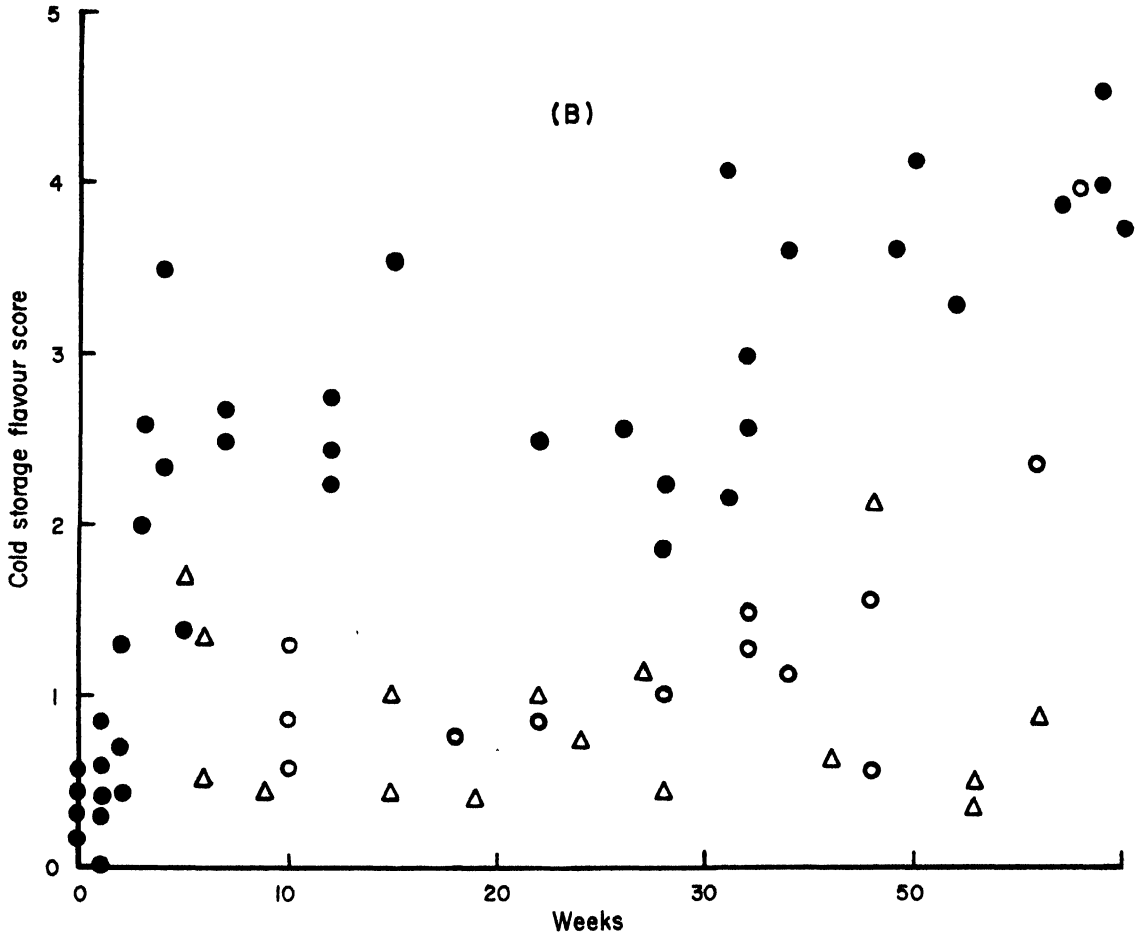


Fig 4(b). Changes in cold storage flavour scores in cod of different initial freshness held at different temperatures of storage in the frozen state, five days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

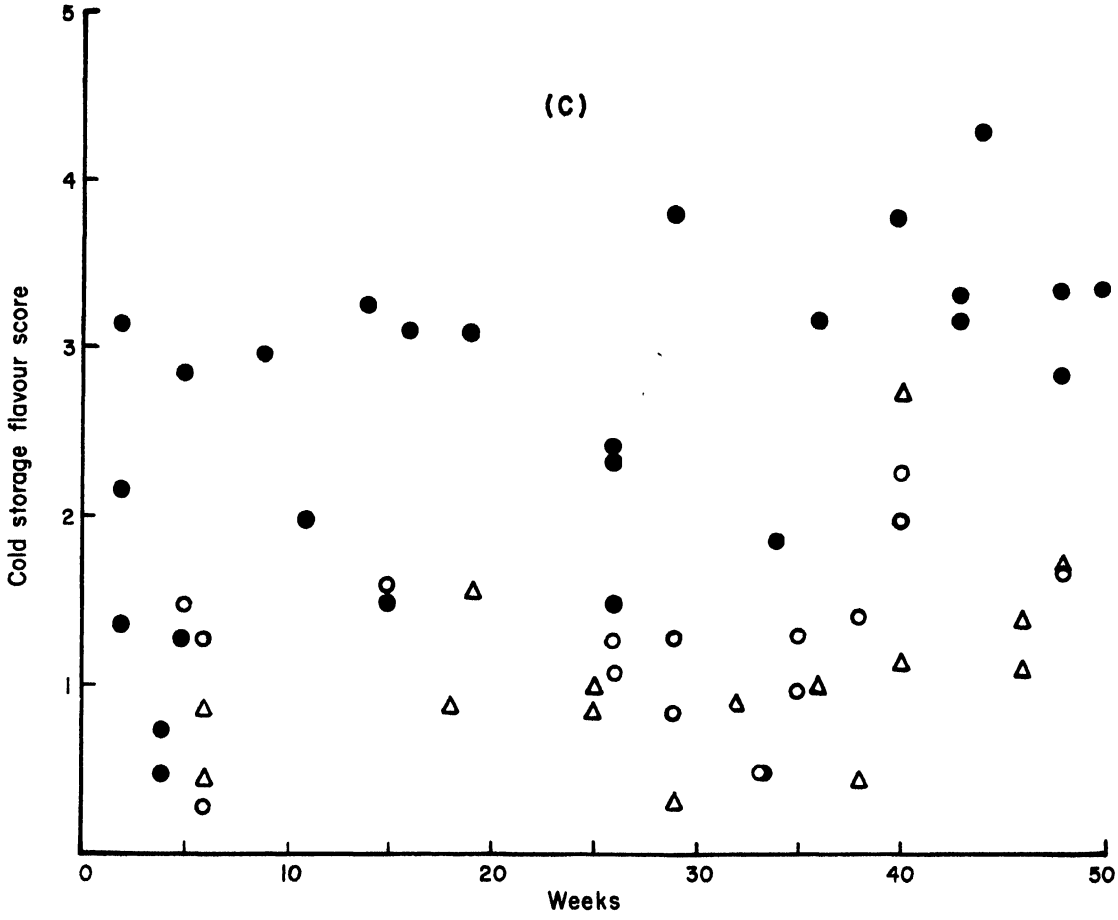


Fig 4(c). Changes in cold storage flavour scores in cod of different initial freshness held at different temperatures of storage in the frozen state, eight days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

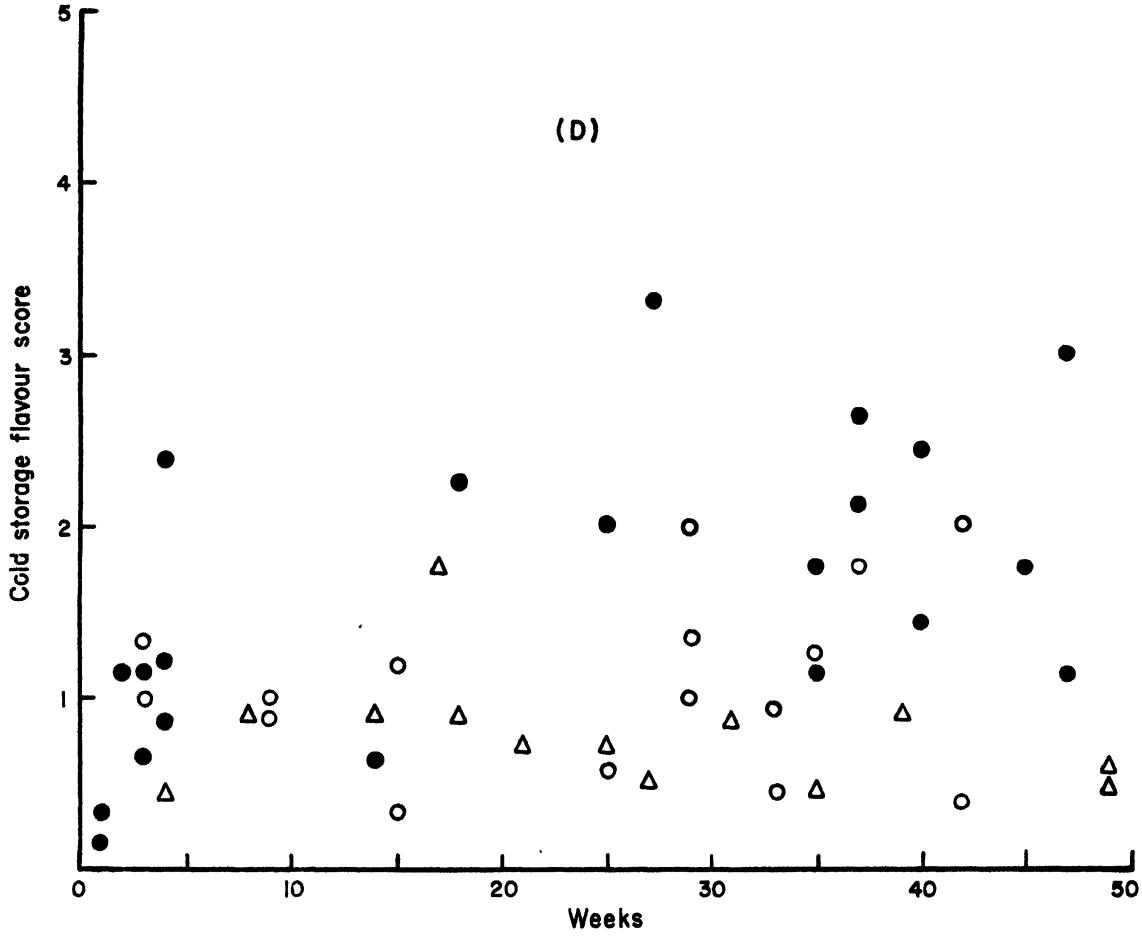


Fig 4(d). Changes in cold storage flavour scores in cod of different initial freshness held at different temperatures of storage in the frozen state, 14 days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

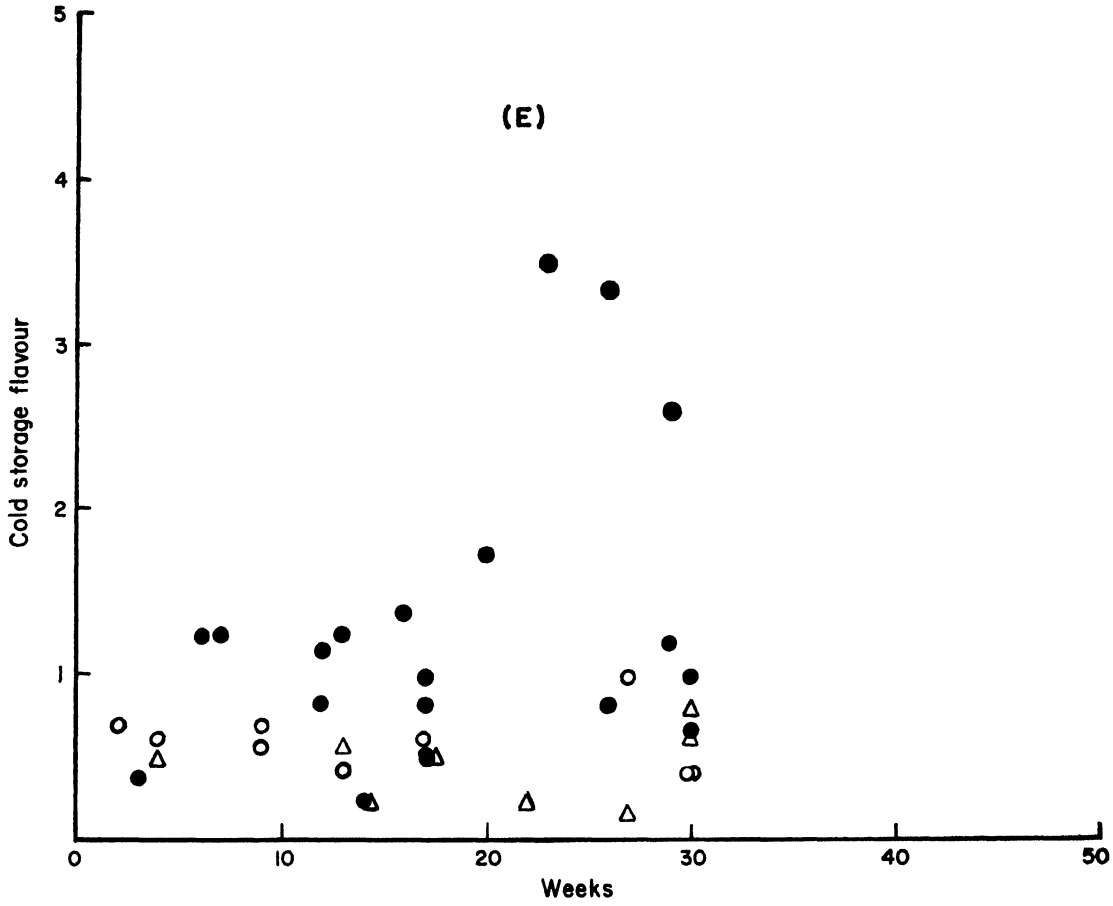


Fig 4(e). Changes in cold storage flavour scores in cod of different initial freshness held at different temperatures of storage in the frozen state, 17 days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

five and eight days in ice and then at −14°C there is a rapid increase in cold storage flavour to the moderate or strong level within the first six to eight weeks followed by a further slow rise over the next 40 weeks to the strong or very strong level. The increases at −22°C are much less, and at −29°C very slight. With fresh fish of this kind it is possible to detect the development of cold storage flavour within one week at −14°C. Inspection of the results shows that the rate of development varies considerably from fish to fish. In the case of stale fish, stored initially for 14 or 17 days, the increase in cold storage flavour is much less at the same temperature of frozen storage than the fresher fish. It is not clear at this stage whether this is because the actual chemical changes responsible for the development of cold storage flavour occur less rapidly in the stale fish or because the cold storage flavour is masked by the pronounced bacterial spoilage flavours. The change in cold storage flavour scores at −22° and −29°C can be adequately represented by a linear or exponential regression, but those at −14°C cannot. No objective methods are as yet available which are designed specifically to monitor changes in cold storage flavours or odours. However, the values of protein extractability, colour ratio and cell fragility do change in a more or less regular manner during storage in the frozen state and it is possible that measurement of any of these three parameters would offer a means of predicting levels of cold storage flavour; this possibility is briefly examined later in this paper.

Changes in firmness with storage time are shown in fig 5. At a storage temperature of −14°C firmness increases rapidly in the initially fresher fish from a value of about 2.3 to a value of nearly 4 (slightly tough) within the first six to eight weeks, and then increases more slowly to a value of about 4.5 at 50 weeks. The starting value of about 2.3 is higher than that of the average value of 2.0 for unfrozen North Sea cod because there is a demonstrable increase of firmness on freezing and thawing without intermediate storage. In the stale fish, that is 14 and 17 days in ice, the rate of increase at −14°C is much less and hardly reaches a value of 4 after 50 weeks. It is possible that this phenomenon is due to the fact that initially staler fish tends to become less firm than fresher fish during frozen storage. However, it is felt that it is more likely to be because stale fish is softer and "mushier" than fresh fish to the palate, and this difference is retained throughout freezing and frozen storage. At a storage temperature of −22°C there is in all cases a smaller rate of increase in firmness, and at −29°C only a very slight increase. Kelly *et al.* (1966) have shown that the texture of cod is dependent upon the ultimate pH of the flesh, cod which have a low ultimate pH being tougher or firmer than cod of high ultimate pH. Analysis of the present results shows that the material examined exhibits

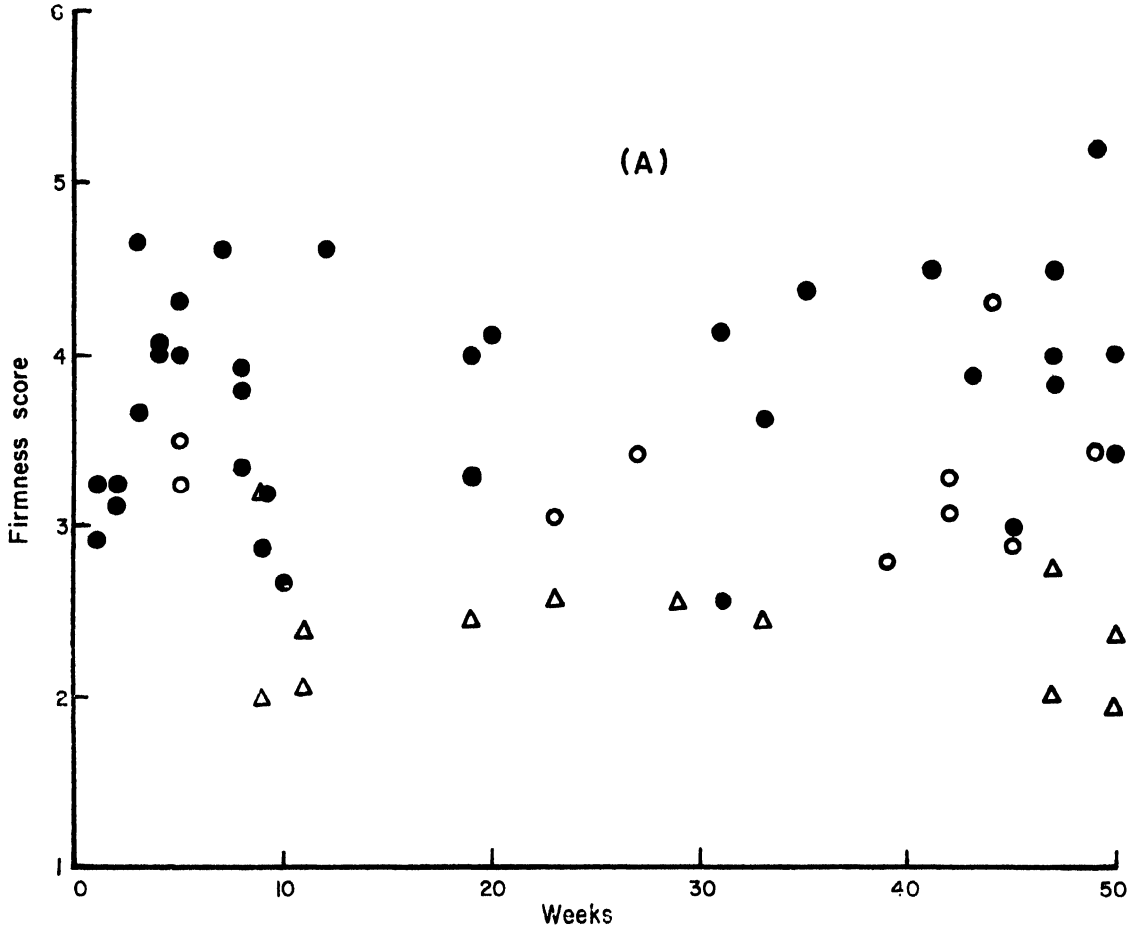


Fig 5(a). Changes in firmness scores of cod of different initial freshness held at different temperatures of storage in the frozen state, two days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

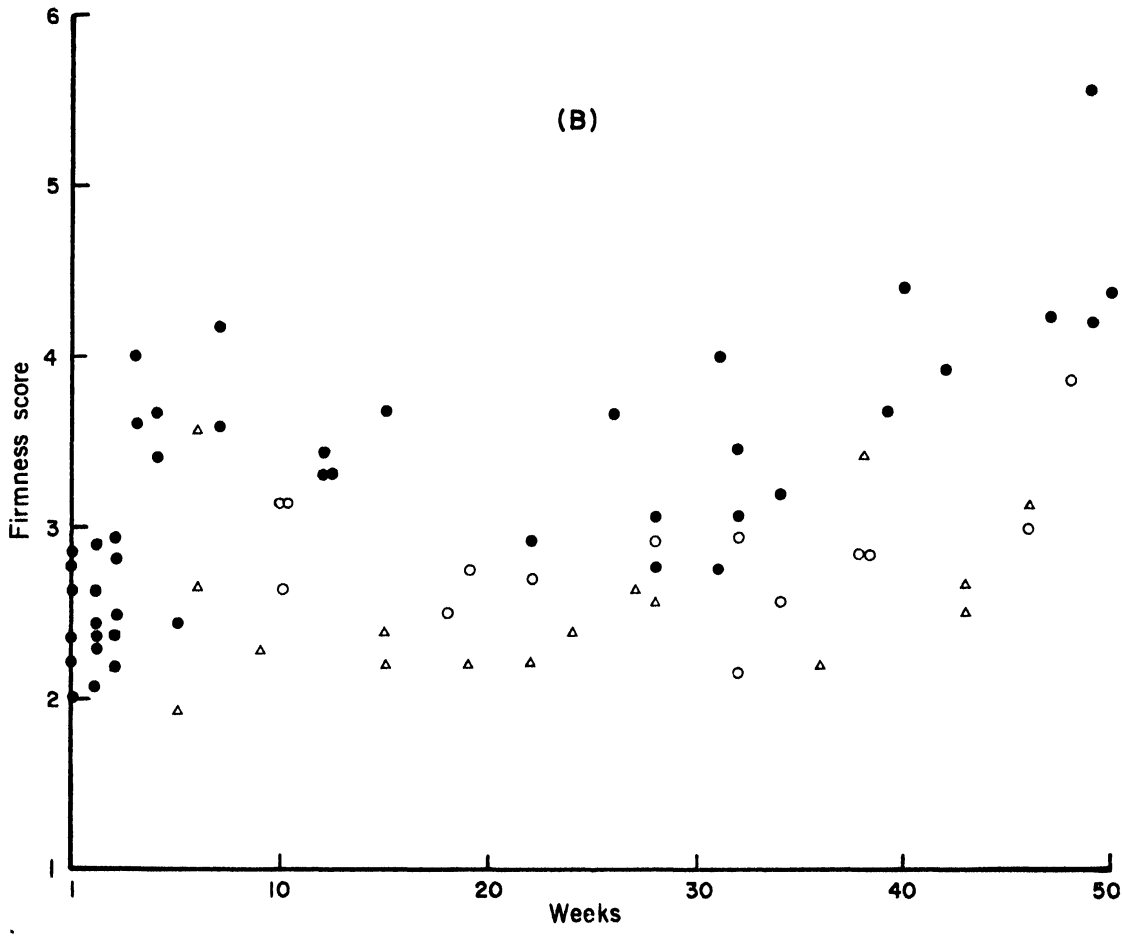


Fig 5(b). Changes in firmness scores of cod of different initial freshness held at different temperatures of storage in the frozen state, five days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

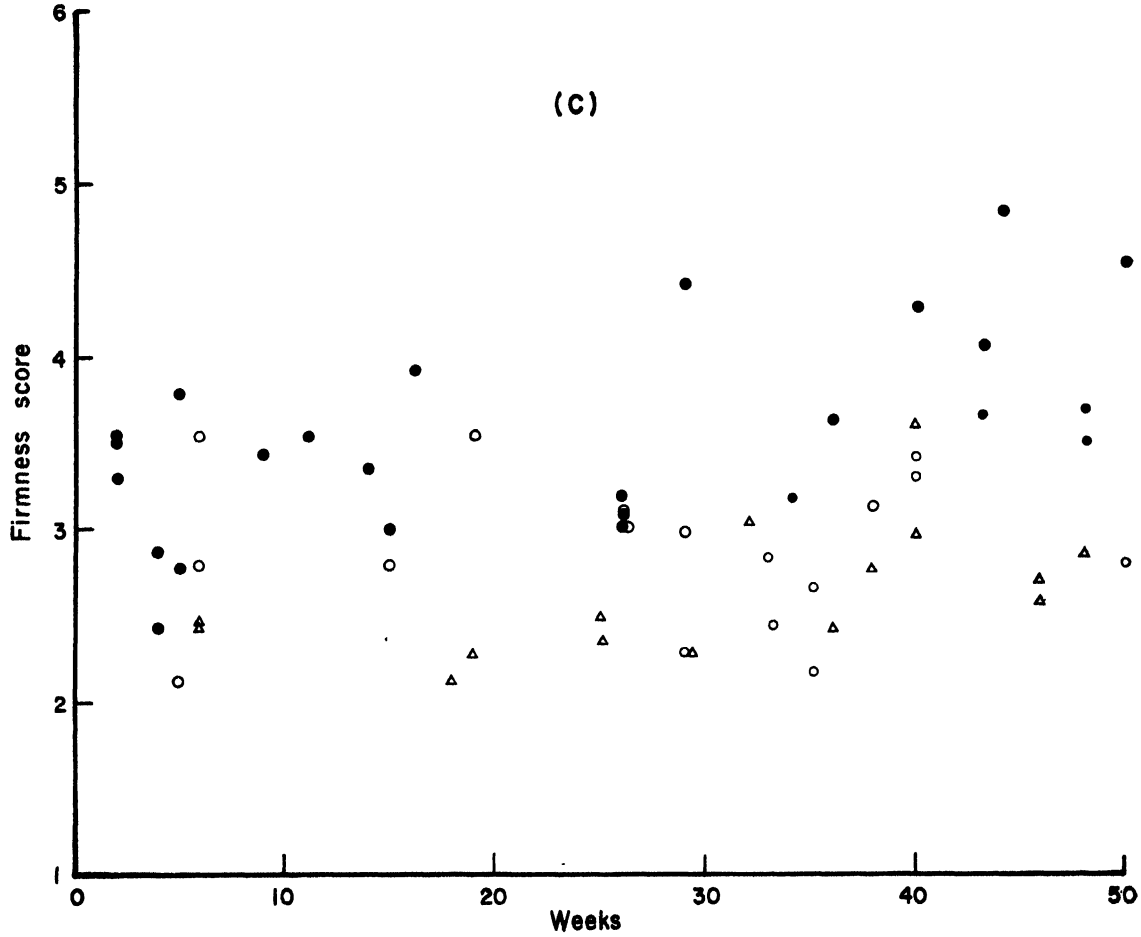


Fig 5(c). Changes in firmness scores of cod of different initial freshness held at different temperatures of storage in the frozen state, eight days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

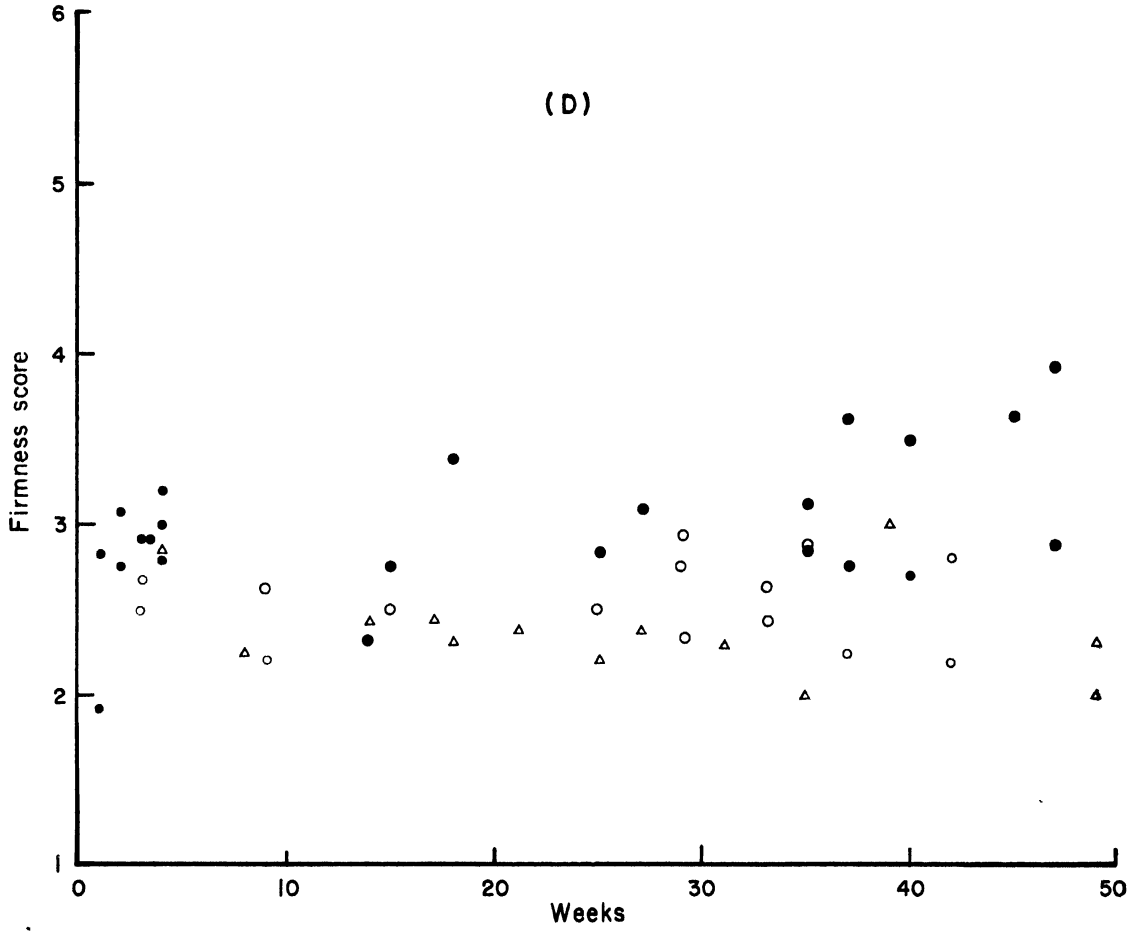


Fig 5(d). Changes in firmness scores of cod of different initial freshness held at different temperatures of storage in the frozen state, 14 days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

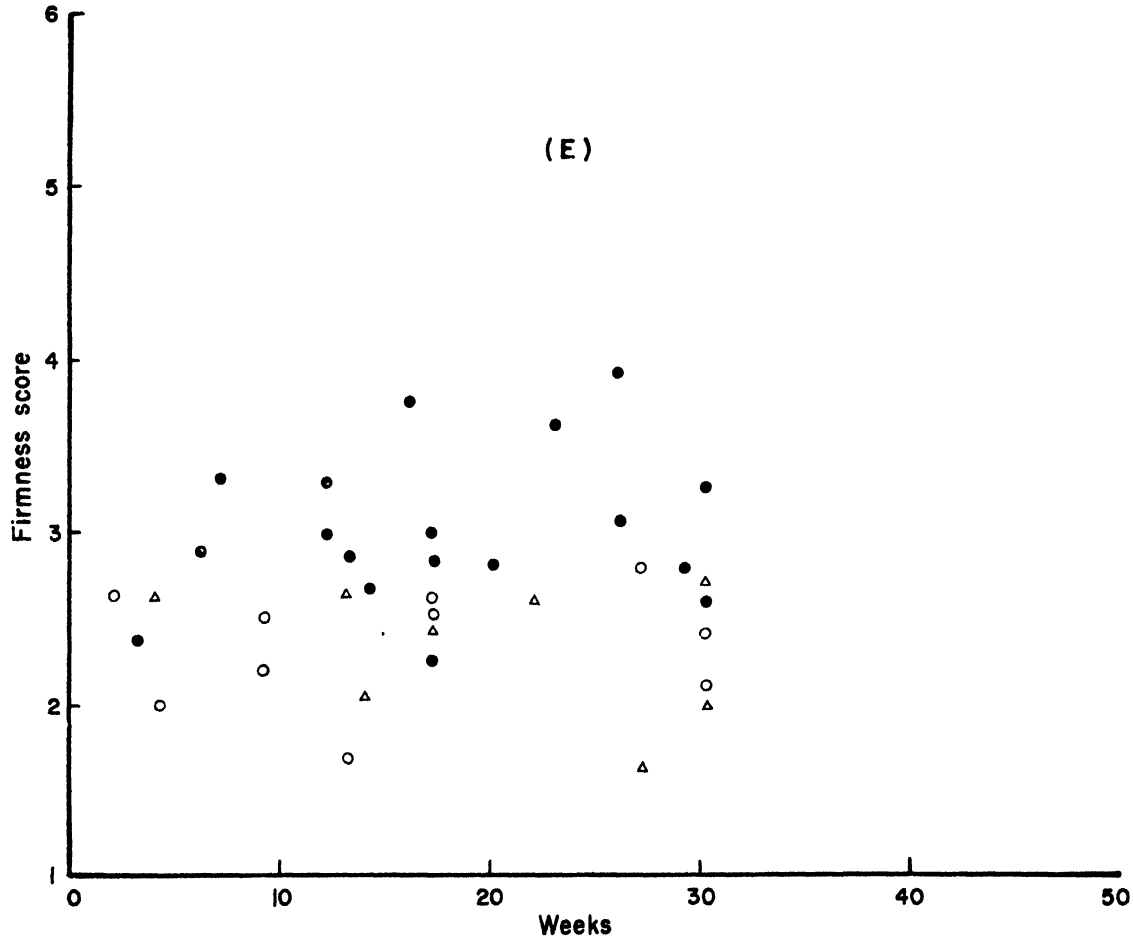


Fig 5(e). Changes in firmness scores of cod of different initial freshness held at different temperatures of storage in the frozen state, 17 days in ice before freezing. Fish stored at: ●, −14°C; ○, −22°C; △, −29°C

the same behaviour in that firmness scores are inversely related to ultimate pH. This means that the firmness score of any particular sample of frozen and stored cod is not entirely determined by the amount of deterioration undergone during storage but is affected by the ultimate pH as well. One can go some way towards taking into account the variations in firmness due to variations in ultimate pH, by correcting the firmness scores to the average pH of the entire population of samples using the observed relationship between firmness and pH for unfrozen samples of cod. This relationship has been determined for the taste panel and type of cod used in the present work, and employed to correct the firmness scores to the calculated average pH of all the frozen and stored samples used of 6.85. Corrected firmness scores of the two-day ice samples stored at −14°C are shown in fig 6. As expected, the corrected firmness scores show less scatter about the trend with storage time than do the uncorrected scores shown in fig 5. It will be noticed from fig 5 that there appears to be a "dip" in the firmness values at about 20 to 30 weeks' storage, and that this "dip" is smoothed out to some extent in the corrected data. This is almost certainly due to the fact that the ultimate pH varies with season when caught, high pH and consequently low relative firmness scores being associated with the period January to February. This period of the year coincides with the 20 to 30 weeks period of storage in the present work.

Changes in protein extractability, colour ratio and cell fragility will be reported elsewhere, but it can be said here that the behaviour of the first two of these measurements is similar to that already published. On the other hand, the values of cell fragility differ from those reported by Love and MacKay (1962) in that the range of values is less and the rate of decrease with period of storage in the frozen state greater.

Correlation coefficient between protein extractability, colour ratio, cell fragility, cold store flavour and firmness have been calculated for those samples for which all parameters were measured. This calculation (table 3) embraces 139 samples covering all degrees of initial spoilage and cold storage deterioration. It is clear that of the objective measurements, protein extractability correlates much better with either cold storage flavour or firmness than either colour ratio or cell fragility. Of the last two objective measurements, colour ratio correlates with the sensory assessments much better than cell fragility.

TABLE 3. CORRELATION COEFFICIENTS BETWEEN ORGANOLEPTIC AND OBJECTIVE METHODS OF ASSESSING COD OF DIFFERENT INITIAL FRESHNESS HELD AT DIFFERENT TEMPERATURES OF STORAGE IN THE FROZEN STATE

	Protein extractability	*Colour ratio*	*Cell fragility*
Cold storage flavour	−0.730	0.620	−0.476
Firmness	−0.664	0.565	−0.397

In all cases these correlation coefficients are significant at $p < 0.01$.

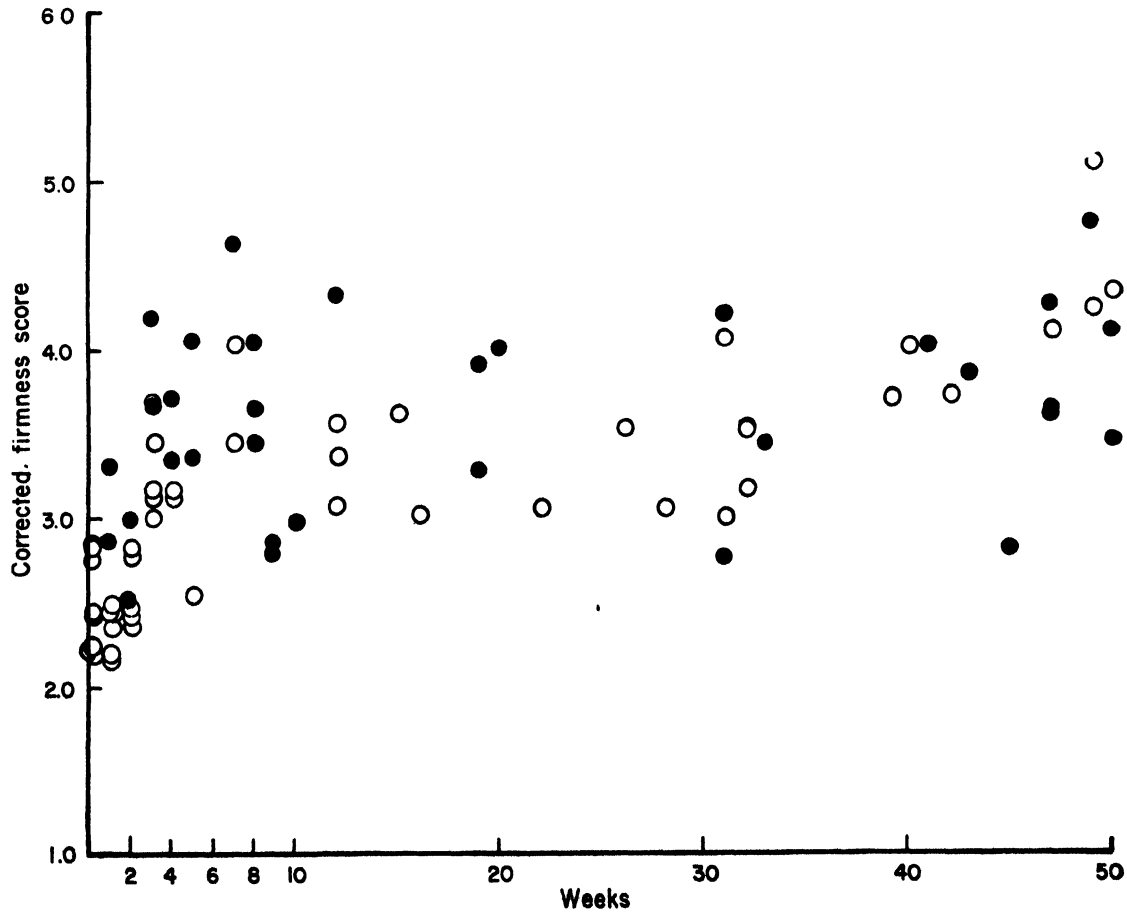


Fig 6. Change in firmness scores corrected for variations of ultimate pH, of cod two days in ice held at −14°C

Acknowledgements

Drs. R. M. Love, J. R. Burt and J. N. Olley arranged to analyse the samples for cell fragility, hypoxanthine and protein extractability respectively. Mr. P. F. Howgate carried out much of the statistical analysis. The work described in this paper was carried out as part of the programme of Torry Research Station.

References

BAINES, C R, CONNELL, J J, GIBSON, D M, HOWGATE, P F, LIVINGSTON, EVELYN I and SHEWAN, J M 1967 FAO Technical Conference on the Freezing and Irradiation of Fish, 4th–8th September, Madrid.

BANKS, A *Annex 1962–1 Bull. int. Inst. Refrig.*, p. 445. 1962

CONNELL, J J *J. Sci. Fd Agric.*, **17**, 329. 1966

DYER, W J, FRASER, DORIS I, MACINTOSH, RUTH G and MYER, MARGARET. 1964 *J. Fish. Res. Bd Can.*, **21**, 577.

EHRENBERG, A S C and SHEWAN, J M *Appl. Statist.*, **8**, 186. 1959

FARBER, L In *Fish as Food*, Academic Press, New York, 1965 **4**, 65.

GOULD, EDITH *Testing the Freshness of Frozen Fish*, Fishing 1965 News (Books) Ltd., London.

IRONSIDE, J I M and LOVE, R M *J. Sci. Fd Agric.*, **9**, 597. 1958

JONES, N R *Proc. XI Int. Congr. Refrig.*, Munich, p. 917. 1963

JONES, N R, MURRAY, J and BURT, J R *J. Fd Sci.*, **30**, 791. 1965

JONES, N R, MURRAY, J, LIVINGSTON, EVELYN I and MURRAY, 1964 C K *J. Sci. Fd Agric.*, **15**, 763.

KELLY, K, JONES, N R, LOVE, R M and OLLEY, J *J. Fd.* 1966 *Technol.*, **1**, 9.

LANE, J P *Fd. Technol., Champaign*, **18**(7), 156. 1964

LOVE, R M and MACKAY, ELEANOR M *J. Sci. Fd Agric.*, **13**, 1962 200.

MURRAY, C K and BURT, J R Proceedings Technical Inter- 1964 national Symposium Automation in Anal. Chem., London.

Factors Affecting the Texture of Frozen Fish

by Kirsteen O. Kelly

Factors affecting the texture of frozen fish

The texture of frozen cod (*Gadus morhua*) can be related to muscle pH and also to the extent of protein denaturation. It is already well established that temperature of cold storage plays an important part in determining the rate of cold storage deterioration.

The present paper describes an investigation which was made to determine the effect of pH on the rate of cold storage deterioration. Cold storage temperatures investigated were −29°, −20° and −10°C (−20°, −4° and +14°F). Results showed significant differences in rate of change of extractable nitrogen, texture score and liquor loss, depending on muscle pH. The lower the pH value of the fillets, the more rapid was deterioration.

From the results, it is concluded that cod with pH values greater than 6.70 are best for long-term cold storage.

Facteurs affectant la texture du poisson congelé

La texture de la morue congelée (*Gadus morhua*) peut être mise en rapport avec le pH du muscle et avec l'ampleur de la dénaturation de la protéine. Il est déjà prouvé que la température de la chambre froide joue un rôle important quant à la vitesse de détérioration en cours d'entreposage frigorifique.

Le présent document décrit une étude effectuée en vue d'établir l'effet du pH sur le temps de détérioration survenant en cours d'entreposage frigorifique. Les températures frigorifiques prises en considération étaient de −29°, −20° et −10°C (−20°, −4° et +14°F). Les résultats ont révélé des différences significatives quant au taux de l'azote extractible, à la note de texture et à la perte de substance liquide qui sont fonction du pH du muscle. Plus le pH des filets était faible, plus rapide était la détérioration.

D'après les résultats de cette recherche, on peut conclure que la morue ayant un pH supérieur à 6,70 est la plus apte à supporter l'entreposage frigorifique à long terme.

Factores que influyen en la textura del pescado congelado

La textura del bacalao congelado (*Gadus morhua*) puede estar relacionada con el pH de la carne y también con el grado de la desintegración proteínica. Está ya bien demostrado que la temperatura a que se realiza el almacenamiento frigorífico desempeña una parte importante en la determinación del tipo de deterioración que se da en él.

En este estudio se expone la investigación efectuada para determinar el efecto del pH en el tipo de deterioración en almacenamiento frigorífico. Las temperaturas de tal almacenamiento investigadas fueron de −29°, −20° y −10°C (−20°, −4° y +14°F). Los resultados indicaron diferencias importantes, según el pH de la carne, en la velocidad de cambio del nitrógeno extraíble, en las condiciones de la textura y en la pérdida de humedad. Cuanto más bajo era el valor del pH en los filetes más rápida fue la deterioración.

De los resultados se deduce que el bacalao con valores de pH superiores a 6,70 es el mejor para su conservación en frío durante largo tiempo.

THE relationship between cod (*Gadus morhua*) muscle pH and some of its quality parameters has previously been reported. Kelly *et al.* (1966) showed the relationship between texture and pH and between cell fragility values and pH. Cod muscle of low pH (<6.40) has a tough cooked texture and high pH (>6.7) a soft cooked texture. Further, variations in cell fragility values were explained by variations in muscle pH.

More recently Cowie and Little (1966, 1967) have reported the importance of both pH and protein extractability in predicting the cooked toughness of frozen cod muscle. They found that at low storage temperatures (−29°C, −20°F), pH was all important in determining texture. At higher storage temperatures (−14°C, +7°F and −7°C, +20°F) both pH and the extent of protein denaturation were important in determining eating texture.

The present paper describes work carried out to find the relationship between muscle pH and the rate of cold storage deterioration. The parameters which were used to measure changes during cold storage were:

(1) texture and flavour
(2) toughness
(3) liquor loss
(4) extractable nitrogen

Three different storage temperatures were used: −29°C (−20°F) and −20°C (−4°F) which are recognized as acceptable for preservation and −10°C (+14°F) which is too high for satisfactory cold storage.

EXPERIMENTAL

Fish selection

Codling (*Gadus morhua*) were purchased on Aberdeen market in a very fresh condition (i.e. within three days of catching). The fish weighed between 2 and 4 kg, and were filleted as soon as possible after purchase. The fillets were all classified into groups according to the muscle pH. The middle cut of each fillet was used and the pH measured at the anterior and posterior ends of this cut. If the pH of both ends of the fish did not fall within the limits of the same group it was discarded. The pH groups chosen were as follows:

(1) pH >6.70
(2) pH 6.40–6.70
(3) pH <6.40.

Experimental plan

Initially the effect of muscle pH on storage qualities was studied at temperatures of −29°C (−20°F) and −10°C (+14°F). For this the fillets were pH graded, wrapped in polythene pouches and blast frozen. The stored fillets were examined at monthly intervals, and at each time six fillets from each group were used.

In a later experiment storage at −20°C (−4°F) was similarly investigated and eight fillets from each group were examined for quality at monthly intervals. The experiment was designed so that two fillets from one fish were never examined at similar storage times.

Assessment methods

Taste-panel. The fish samples were cooked from the frozen state by steaming for 1 h in a casserole.

Two methods were used to assess the cooked fish. Texture and flavour were scored on a five-point scale where

5= very good
4= good
3= acceptable
2= poor
1= very poor.

Texture characteristics were further defined by use of a two-dimensional scoring system, Cowie and Little (1966), in which toughness/softness and wetness/dryness were assessed. Briefly, the panel are asked to assess the fish for toughness/softness (y) and wetness/dryness (x). When the average value of $x(\bar{x}) = 0$ the fish is wet and when $\bar{x} = 4$ dry. When $\bar{y} = 0$ the fish is soft and $\bar{y} = 4$ tough.

Liquor loss. The method used was that described by Little and Smithies (1964). Forty g samples of the frozen fish were heated at 20°C (68°F) for 1 h and the drip collected.

Extractable nitrogen. 0.5 to 1.0 g of frozen muscle was accurately weighed and placed in 100-ml polythene measuring cylinder containing 100 ml of 5 per cent sodium chloride (adjusted to pH 7.0 with $NaHCO_3$). The mixture was macerated for 15 sec with an Ultra Turrax homogenizer and then centrifuged under refrigeration for 30 min at 2,000 g. All operations were carried out in the cold room. Ten ml of the supernatant were used for soluble nitrogen determinations by the micro-kjeldhal method. Quintuplicate determinations were made. Total nitrogen determinations were made, on 1.0 g samples of the frozen muscle, in triplicate. Extractable nitrogen was determined only on fish which had been stored at −20°C (−4°F).

RESULTS

Taste-panel assessment

Texture and flavour as scored on the five-point scale system showed no significant change during eight months' storage at −29°C (−20°F).

During storage at −20°C (−4°F) fish in the high and low pH groups again remained unchanged but fish in the medium pH group had a significantly lower texture score (fig 1). The texture value for these medium pH fish fell from 3.3 to 2.3 during eight months' storage, that is they had a texture similar to low pH fish. Flavour scores remained acceptable throughout the storage period.

During storage at −10°C (+14°F) marked differences in rate of change in texture and flavour were observed between the three pH groups (figs 2 and 3). Low pH fish deteriorated more quickly than medium pH fish, which in turn deteriorated more quickly than high pH fish. For example a texture score of 2.5 was reached by low pH fish within one month of storage, by medium pH fish after three months' storage and by high pH fish after six months' storage.

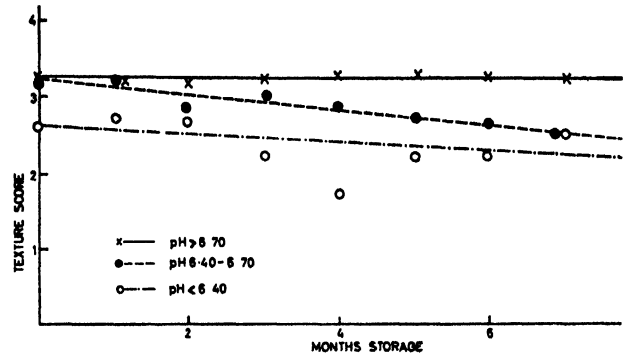


Fig 1. Relationship between texture score, pH and storage time at −20°C(−4°F) of cod fillets

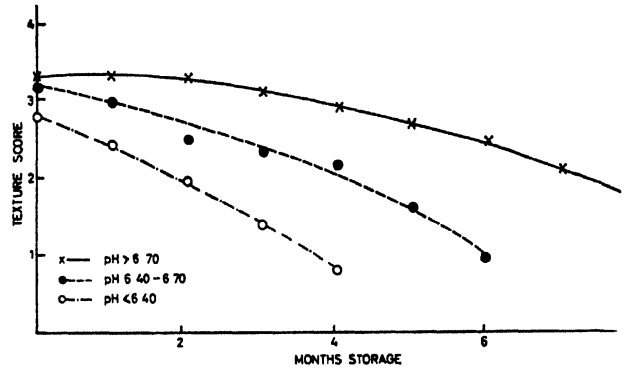


Fig 2. Relationship between texture score, pH and storage time at −10°C (+14°F) of cod fillets

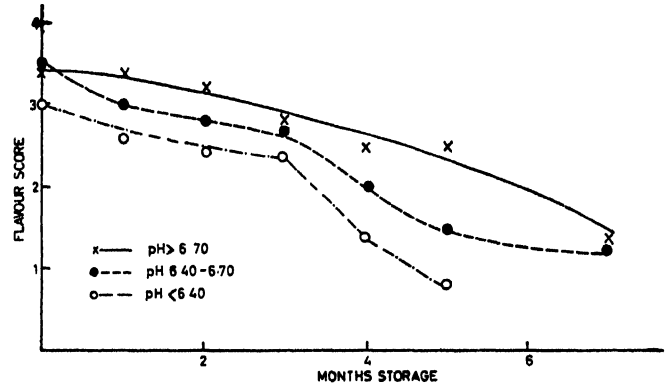


Fig 3. Relationship between flavour score, pH and storage time at −10°C (+14°F) of cod fillets

A similar pattern was found with flavour scores where low pH fish deteriorated more rapidly than fish in the higher pH groups.

The toughness score ($\bar{y}$) for freshly frozen cod is dependant on the muscle pH. The low pH fish have tough textures and increases in pH give less tough textures. These initial differences in toughness between the fish of different pH groups were still present after storage. There were slight increases in $\bar{y}$ score during storage but the rate of change was not apparently affected

by muscle pH. Fig 4 shows results for −20°C (−4°F) storage only, but are representative of results obtained at −29° and −10°C (−20° and +14°F).

In no case were significant changes observed from wet/dry ($\bar{x}$) scores.

Liquor loss

The measurement of liquor lost from cold-stored cod, when heated to 20°C (68°F) for 1 h, can be used as a measure of deterioration during storage. Measurements showed there was little change at −29°C (−20°F). At −20°C (−4°F) slight increases in liquor loss occurred (fig 5), and at −10°C (+14°F) there were marked differences between the fish in different pH groups (fig 6). The small, but quite distinct, differences in liquor loss in freshly frozen fish were greatly increased. The greatest increase was found with fish of low pH values.

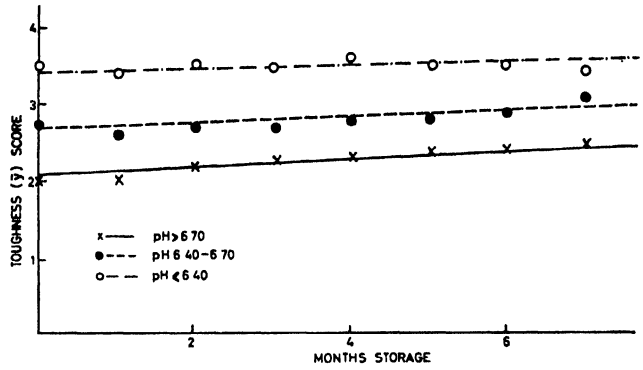


Fig 4. Relationship between toughness ($\bar{y}$) score, pH and storage time at −20°C (−4°F) of cod fillets

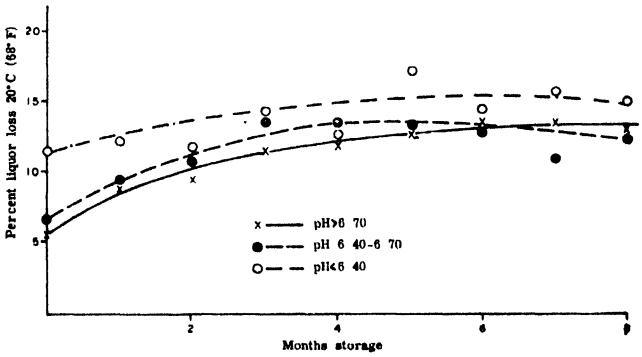


Fig 5. Relationship between liquor loss, pH and storage time at −20°C (−4°F) of cod fillets

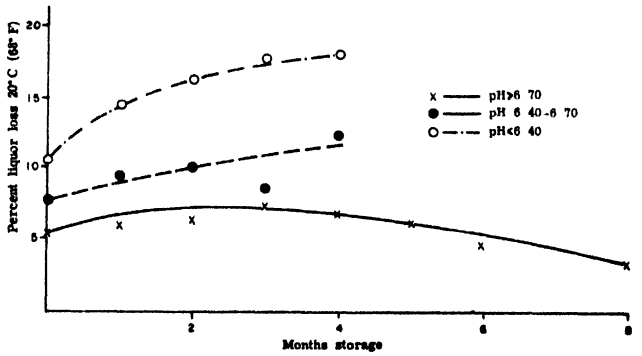


Fig 6. Relationship between liquor loss, pH and storage time at −10°C (+14°F) of cod fillets

Extractable nitrogen

Decreases in extractable nitrogen were found during storage at −20°C (−4°F) (fig 7). The fitted regression lines for the three pH groups are:

(1) pH >6.70
Extractable nitrogen
= 85.00 − 0.74 × months storage

(2) pH 6.40–6.70
Extractable nitrogen
= 89.75 − 1.7805 × months storage

(3) pH <6.40
Extractable nitrogen
= 86.85 − 2.38 × months storage

These results have shown that rate of change in extractable nitrogen, and thus protein, during cold storage is at least in part determined by the pH of the flesh.

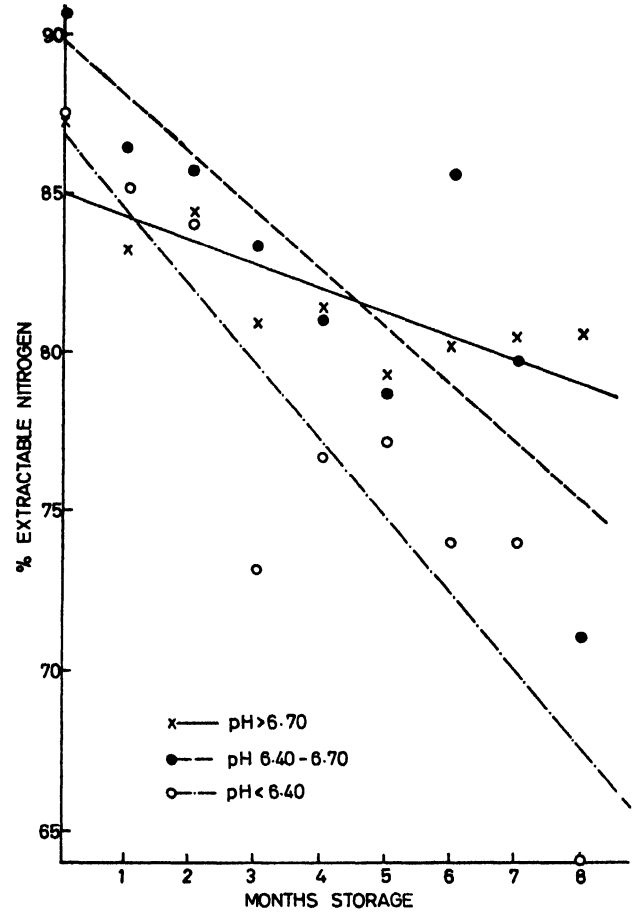


Fig 7. Relationship between extractable nitrogen, pH and storage time at −20°C (−4°F) of cod fillets

DISCUSSION

The results have shown that pH of cod muscle has an effect on the rate of change of certain quality parameters during cold storage. Predictably the effect was most pronounced when the storage temperature was −10°C (+14°F), a temperature at which changes are known to occur rapidly. However, differences were also observed during storage at −20°C (−4°F).

The extractable nitrogen, texture, liquor loss and flavour assessments all showed different rates of change

depending on pH. It was, however, interesting to find that when toughness ($\bar{y}$) was plotted against storage time for the three pH groups, the curves obtained were parallel. That is, the rate of change was independent of muscle pH. The spread of ($\bar{y}$) scores between pH groups, at the beginning and end of storage, were similar.

What is the significance of these results in terms of fish processing? There are two obvious questions which should be answered:

(1) What is the pH distribution of commercial cod?

(2) Should any limitations be put on storage time of fish with different pH values?

Limited surveys have been carried out in order to determine the occurrence of fish with different pH values. Over a period of six months fish landed at Aberdeen were measured for pH values and the results obtained are shown in table 1.

TABLE 1. PERCENTAGE OF FISH IN DIFFERENT pH GROUPS

	pH groups		
	pH <6.40	*pH* 6.40–6.70	*pH* >6.70
Cod (3.5–4.0 kg)	25	50	25
Codling (0.7–1.0 kg)	0.5	20	79.5
Haddock (0.5 kg)	24	74	2

A further survey carried out in Newfoundland during the trap-cod season showed that 40 per cent of the fish were pH <6.40, 35 per cent between pH 6.40 and 6.70 and the remainder pH >6.70.

From the results, the storage potential of cod depends on muscle pH. High pH fish appear to be very much more stable than fish of low pH during cold storage and for this reason are considered best for long-term cold storage. In fact, we have found that high pH fish which are soft initially, actually improve slightly on storage due to increase in toughness ($\bar{y}$) score.

References

COWIE, W P and LITTLE, W T *J. Fd Technol.*, **1**, 335. 1966

COWIE, W P and LITTLE, W T *Ibid.* (In press.) 1967

KELLY, K O, JONES, N R, LOVE, R M and OLLEY, J *Ibid.*, **1**, 9. 1966

LITTLE, W T and SMITHIES R H *Chem. Ind.*, p. 1294. 1964

Rate of Survival of Organisms of Sanitary Significance During Freezing and Subsequent Storage

by A. Lekshmy, D. R. Choudhuri and V. K. Pillai

Rate of survival of organisms of sanitary significance during freezing and subsequent storage

The rate of survival of different types of faecal organisms like *E. coli* and enterococci occurring along with the normal flora of processed fishery products during freezing and subsequent storage at −23.3°C (−10°F) has been studied. Trials on cooked peeled frozen prawns with an added inoculum of a mixture of the above organisms showed that there is a significant reduction in coliform counts during freezing. Subsequent storage at −23.3°C (−10°F) shows almost complete destruction within three to four months of storage. Faecal *Streptococci* on the other hand, showed comparatively higher resistance during freezing, the maximum being 55 to 60 per cent.

Survival rates of individual species of organisms comprising the two major groups of organisms shown above were investigated in detail and their practical importance discussed. *E. coli* types I and II, *E. freundii* types I and II, *Aerobacter aerogenes* types I and II, and *S. faecalis*, *S. faecalis* var. *liquefaciens*, *S. faecalis* var. *zymogenes*, *S. durans* and *S. bovis* were used in these detailed studies. Of all the strains used, *S. faecalis* var. *liquefaciens* has been found to be of more practical importance to judge factory sanitation than *E. coli*.

Taux de survie d'organismes présentant une importance du point de vue de l'hygiène durant la surgélation et l'entreposage ultérieur

L'étude porte sur le taux de survie de divers types d'organismes fécaux tels que *E. coli* et entérocoques qui accompagnent la flore normale des produits de la pêche traités durant la surgélation et le stockage ultérieur à −23,3°C (−10°F). Les expériences effectuées sur des crevettes décortiquées et cuites surgelées avec adjonction d'inoculum d'un mélange des organismes ci-dessus ont révélé une diminution marquée du nombre des coliformes durant la surgélation. On assiste à la disparition presque complète de ces organismes après trois à quatre mois d'entreposage ultérieur à −23,3°C (−10°F). Par contre, les *Streptocoques* fécaux résistent comparativement davantage durant la surgélation, le taux maximal de destruction observé étant de 55 à 60 pour cent.

Les auteurs ont étudié à fond, et examiné la portée pratique, des taux de survie des diverses espèces d'organismes constituant les deux grands groupes indiqués plus haut. Ces travaux détaillés ont porté sur *E. coli*, types I et II, *E. freundii* types I et II, *Aerobacter aerogenes* types I et II et *S. faecalis*, *S. faecalis* var. *liquefaciens*, *S. faecalis* var. *zymogenes*, *S. durans* et *S. bovis*. On a constaté que parmi toutes les souches employées, *S. faecalis* var. *liquefaciens* présentait davantage d'importance pratique que *E. coli* comme indicateur de l'état d'hygiène des installations.

Supervivencia de los organismos de importancia sanitaria durante la congelación y el almacenamiento subsiguiente

Se estudia la supervivencia de diferentes tipos de organismos fecales como el *E. coli* y enterococci que durante la congelación, y el subsiguiente almacenamiento a la temperatura de −23,3°C (−10°F) se encuentran entre la flora normal de los productos pesqueros elaborados. Las pruebas efectuadas con camarones cocidos, pelados y congelados, a los que se ha adicionado un inóculo de una mezcla de los anteriores organismos, demostraron que durante la congelación se produce una importante disminución de los coliformes. El posterior almacenamiento a −23,3°C (−10°F) puso de manifiesto una destrucción casi completa a los tres o cuatro meses. Los *Estreptococos* fecales, en cambio, mostraron una resistencia comparativamente mayor durante la congelación, del 55 al 60 por ciento como máximo.

Se investigó con todo detalle la supervivencia de las especies individuales de organismos que contienen los dos principales grupos antes indicados, y se discutió su importancia práctica. Para estos estudios detallados se utilizaron el *E. coli*, tipos I y II; el *E. freundii*, tipos I y II; el *Aerobacter aerogenes*, tipos I y II, y los *S. faecalis* var. *liquefaciens*, *S. faecalis* var. *zymogenes*, *S. durans* y *S. bovis*. De todas las razas utilizadas, se encontró que el *S. faecalis* var. *liquefaciens* era de mayor importancia práctica que el *E. coli* para juzgar el estado sanitario de las instalaciones.

PROBLEMS connected with the incidence of faecal organisms like *E. coli*, enterococci and coagulase positive strains of *Staphylococci* in frozen fishery products and their effective control have been engaging the attention of producers and technologists all over the world. Many valuable contributions have been made in recent years on the mode and extent of bacterial contamination in frozen fishery products with the result that minimum permissible limits have been prescribed for the various groups of bacteria in several countries. It has been clearly established that the microbiological condition of a frozen fish product is dependent upon various factors such as the nature of raw material, its pre- and post-process treatments, the sanitary condition of the processing factories, the rate and nature of freezing (Luyet and Gehenio, 1940), the temperature and time of storage (Kereluk and Gunderson, 1959; Larkin, Litsky and Fuller, 1955), the original numbers, types and stages of growth of micro-organisms present (Hess, 1934; Record and Taylor, 1953); thawing processes and physical protection offered by the food (Squires and Hartsell, 1955; Woodburn and Strong, 1960); and on sanitary conditions of the surroundings. The latter can contribute a variety of organisms to the normal load of the product as it moves along the processing lines. It has been clearly established that the presence of organisms belonging to the faecal indicator group and of *Staphylococci* are mainly indicative of the unsanitary condition of the environment and can almost always be traced to polluted water or ice, unwashed containers, slimy floors, etc., in the factories.

Enumeration of the actual levels of the organisms in a frozen fish product is thus an important factor in the production and distribution of frozen fishery products. However, recent studies (Lekshmy, 1964) have shown that these organisms are subject to very wide fluctuations during freezing and subsequent frozen storage. The findings indicated the need for a deeper understanding

of the extent of such fluctuations among the important groups of organisms in order that a rational interpretation of the results will be possible when the counts of a particular group of organism in a frozen fishery product are available. Without this knowledge it was feared that a product which showed *E. coli* count above limit immediately after freezing and accordingly rejected as unfit for human consumption can become acceptable after three to four months of storage at −23.3°C (−10°F), by which time *E. coli* count almost reduces to nil.

The present paper deals with the studies carried out to elucidate the above position fully. The rate and extent of destruction of the different strains of organisms representing the coliform and faecal *Streptococci* groups have been studied using pure strains alone and in various combinations. As a preliminary to this study, products from known unhygienic factory surrounds and those prepared under simulated conditions were examined for the presence of various types of organisms represented in the above-mentioned groups.

EXPERIMENTAL PROCEDURE

Different strains of coliform bacteria, like *E. coli* types I and II, *Aerobacter aerogenes* types I and II, *E. freundii* types I and II, *Streptococcus faecalis*, *S. faecalis* var. *liquefaciens*, *S. faecalis* var. *zymogenes*, *S. durans* and *S. bovis* were inoculated into 1.0 per cent peptone water at 37°C (99°F) for 24 h. Dip solutions were prepared containing varying amounts of bacterial suspension. Fresh peeled and deveined, as well as cooked prawns were soaked in the suspension for 10 to 15 min. The treated samples were taken in 500-g lots and subjected to quick freezing at −40°C (−40°F). Frozen samples were stored at −23.3°C (−10°F). Samples were removed periodically from the storage and tested for the number of coliforms and enterococci.

Enumeration of *E. coli* was carried out as per methods given in earlier communications (Lekshmy, 1964). KF-Agar medium of Kenner (1961) was used for the enumeration of total enterococci count.

Statistical analysis of the bacterial count was carried out by converting them to their logorithmic values (Fisher *et al.*, 1957) and in the cases of percentages they were converted into degrees ϕ by using the transformation

$$P\,(\%) = \sin^2 \phi$$

RESULTS AND DISCUSSION

The results of the preliminary study carried out on factory samples and on samples under simulated unsanitary conditions are given in table 1. These show that almost all the strains representing the two groups are present in varying degrees in the product, the most predominant being *E. coli* type I among the coliforms and *Streptococcus faecalis* and *S. faecalis* var. *liquefaciens* among the faecal *Streptococci*. The former was found to be present to the extent of 50 to 65 per cent of the total while the latter two constituted between 50 to 60 per cent and 40 to 55 per cent of the total enterococci counts.

Results obtained from freezing studies carried out with individual strains alone and in combinations inoculated on cooked and sterile prawn meat as well as on meat with the natural flora have been statistically analysed to examine the significance of the rate of reduction of the organisms during freezing and subsequent storage. The analysed data obtained for individual strains of coliforms, faecal *Streptococci*; mixed strains of *Streptococci*; coliform and *Streptococci* in combinations inoculated on cooked and sterile meat are given in tables 2 to 5, while that obtained for the series with natural flora are given in table 6. The trend in the change of total count of individual strains of coliform and *Streptococci* from a typical series during freezing and subsequent storage are shown graphically in figs 1 and 2.

TABLE 1. NATURAL DISTRIBUTION OF FAECAL ORGANISMS IN FROZEN FISHERY PRODUCTS

Species	*Percentage*
Streptococcus faecalis	50–60
S. faecalis var. *liquefaciens*	40–55
S. durans	3–5
S. bovis	1–2
E. coli type I	50–65
E. coli type II	5–10
Aerobacter aerogenes type I	15–25
A. aerogenes type II	10–20
E. freundii type I	1–5
E. freundii type II	1–3
Irregular varieties	2–5

All pure strains of *E. coli* type I 86 and 122, *E. coli* type II 8164, *A. aerogenes* type I 10336, *A. aerogenes* type II 8167, *E. freundii* type I 8165 and *E. freundii* type II 6071 (table 2) showed significant reduction at 1 per cent level during freezing and storage. When mixed cultures of coliform and streptococci (table 5) were used the rate of reduction of each individual strain was also significant at 1 per cent level, although comparatively higher with the coliforms than *Streptococci* (figs 1 and 2). In cases of *S. faecalis* + *E. coli* type I, *E. freundii* type I + *S. bovis*, *A. aerogenes* + *S. bovis*, *E. coli* type I + *S. faecium* and *S. faecalis* var. *liquefaciens* + *E. coli* type I interactions between block × strain and storage period × strain were significant at 5 per cent level and 1 per cent level respectively, whereas, in the case of *S. faecalis* var. *liquefaciens* + *E. coli* type I and *S. faecalis* + *E. coli* type II interactions were significant at 1 per cent level.

During freezing and frozen storage the reduction of the counts of enterococci, viz. *Streptococcus faecalis* 1137 and LMB_2, *S. faecalis* var. *liquefaciens* 309–2, *S. bovis* TM/C/101 and *S. facium* HGH–511 (table 2) were significant at 1 per cent level but reduction was not significant at 5 per cent level with the strains of *S. faecalis* var. *zymogenes* 1143 and *S. durans* 1133. In mixed cultures of *Streptococci* (table 4) viz. *S. durans* 1133 + *S. faecalis* var. *zymogenes* 1143 total reduction during freezing and subsequent storage became significant at 1 per cent level. In case of *S. faecalis* + *S. faecalis* var. *liquefaciens* 309–2, the reduction was not significant at 5 per cent level but when percentages of *S. durans* 1133 and *S. faecalis* var. *liquefaciens* 309–2 were considered separately in their respective mixtures, their rate of reduction became non-significant at 5 per cent level. In all the cases when *S. durans* was present separately or in combination with other strains its reduction became non-significant at 5 per cent level. Though it is thus highly resistant to

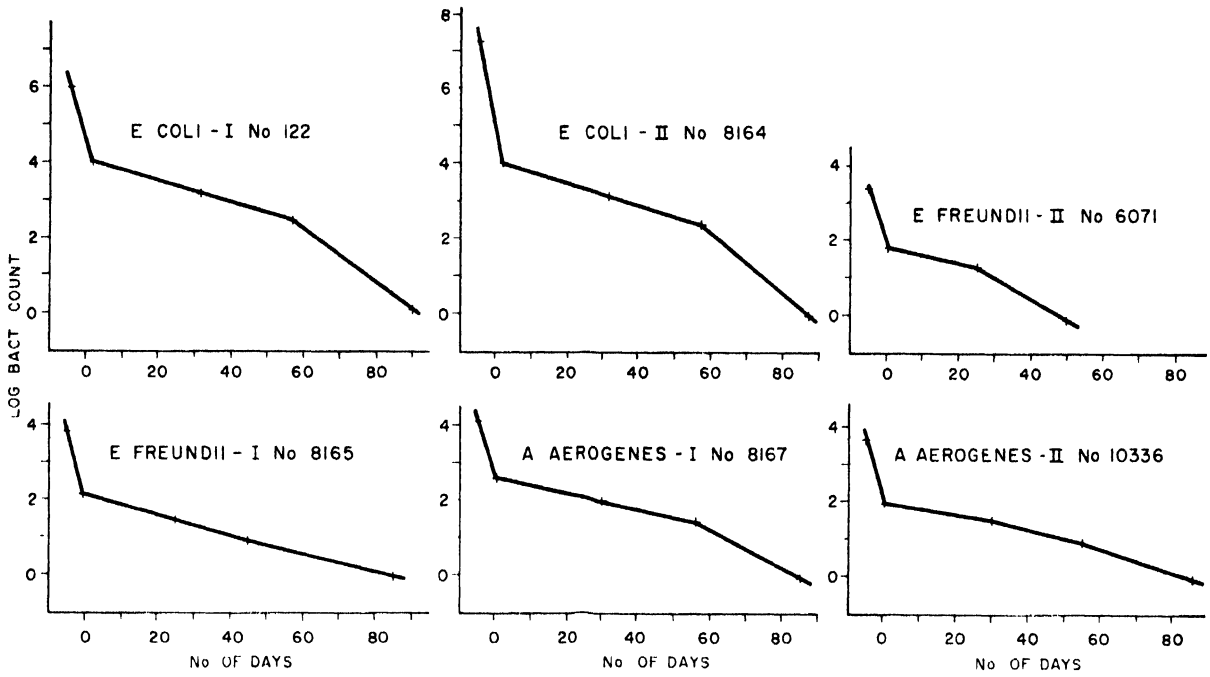


Fig 1. Effect of freezing and frozen storage on individual strains of coliforms

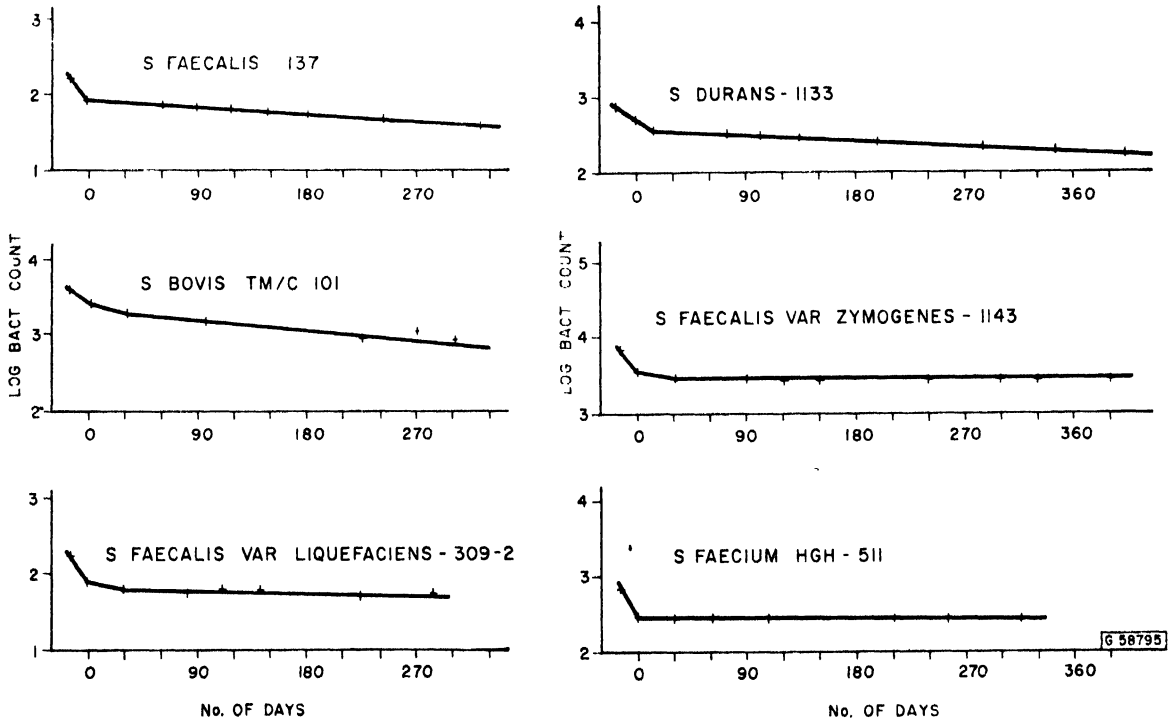


Fig 2. Effect of freezing and frozen storage on individual strains of faecal Streptococci

TABLE 2. ANALYSIS OF VARIANCE OF THE RATE OF DESTRUCTION OF THE COLIFORM ORGANISMS SUBJECTED TO FREEZING AND FROZEN STORAGE

(A) *E. coli* type I no. 86

Source	*S.S.*	*D.F.*	*M.S.*
Total	30.5352	17	
Between blocks	7.8890	2	3.9445†
Between storage periods	20.2902	5	4.0580†
Error	2.3560	10	0.2356

(B) *E. coli* type I no. 122

Source	*S.S.*	*D.F.*	*M.S.*
Total	56.4856	17	
Between blocks	11.0625	2	5.5313†
Between storage periods	38.9331	5	7.7866†
Error	6.4900	10	0.6490

(C) *E. coli* type II no. 8164

Source	*S.S.*	*D.F.*	*M.S.*
Total	39.3025	17	
Between blocks	7.0721	2	3.5361†
Between storage periods	28.5277	5	5.7055†
Error	3.7027	10	0.3703

(D) *A. aerogenes* 10336

Source	*S.S.*	*D.F.*	*M.S.*
Total	37.5787	17	
Between blocks	8.3630	2	4.1815†
Between storage periods	24.6183	5	4.9237†
Error	4.5974	10	0.4597

(E) *A. aerogenes* type II no. 8167

Source	*S.S.*	*D.F.*	*M.S.*
Total	59.9546	23	
Between blocks	4.9337	3	1.6446*
Between storage periods	51.6716	5	10.3343†
Error	3.3493	15	0.2232

(F) *E. freundii* type I no. 8165

Source	*S.S.*	*D.F.*	*M.S.*
Total	37.6296	17	
Between blocks	3.4877	2	1.7439
Between storage periods	26.1947	5	5.2389†
Error	7.9472	10	0.7947

(G) *E. freundii* type II no. 6071

Source	*S.S.*	*D.F.*	*M.S.*
Total	22.7694	11	
Between blocks	0.9777	1	0.9777*
Between storage periods	21.2794	5	4.2559†
Error	0.5123	5	0.1025

* Denotes significance at 5 per cent level.
† Denotes significance at 1 per cent level.
S.S. Sum of squares.
D.F. Degrees of freedom.
M.S. Mean square.

TABLE 3. ANALYSIS OF VARIANCE OF THE RATE OF DESTRUCTION OF FAECAL STREPTOCOCCI SUBJECTED TO FREEZING AND FROZEN STORAGE

(A) *S. faecalis* no. 1137

Source	*S.S.*	*D.F.*	*M.S.*
Total	63.5325	49	
Between blocks	53.5007	4	13.3752†
Between storage periods	7.3143	9	0.8127†
Error	2.7175	36	0.0755

(B) *S. faecalis* var. *liquefaciens* no. 309–2

Source	*S.S.*	*D.F.*	*M.S.*
Total	77.2999	49	
Between blocks	75.8396	4	18.9599†
Between storage periods	0.9270	9	0.1030†
Error	0.5333	36	0.0148

(C) *S. faecalis* var. *zymogenes* no. 1143

Source	*S.S.*	*D.F.*	*M.S.*
Total	38.9885	49	
Between blocks	38.1575	4	9.5394†
Between storage periods	0.2727	9	0.0303
Error	0.5583	36	0.0155

(D) *S. durans* no. 1133

Source	*S.S.*	*D.F.*	*M.S.*
Total	43.5180	39	
Between blocks	42.3953	3	14.1318†
Between storage periods	0.9642	9	0.1071
Error	0.1585	27	0.0587

(E) *S. bovis* TM/C/101

Source	*S.S.*	*D.F.*	*M.S.*
Total	50.8706	27	
Between blocks	49.6521	3	16.5507†
Between storage periods	1.0500	6	0.1750†
Error	0.1685	18	0.00936

(F) *S. faecium* HGH no. 511

Source	*S.S.*	*D.F.*	*M.S.*
Total	30.2176	31	
Between blocks	29.8601	3	9.9534
Between storage periods	0.2838	7	0.0405
Error	0.0737	21	0.0035

(G) *S. faecalis* LMB_2

Source	*S.S.*	*D.F.*	*M.S.*
Total	43.7983	49	
Between blocks	43.2419	4	10.8105†
Between storage periods	0.3209	9	0.0357†
Error	0.2355	36	0.0065

(H) *S. faecalis* var. *zymogenes* no. 1145

Source	*S.S.*	*D.F.*	*M.S.*
Total	11.7652	39	
Between blocks	9.0476	3	3.0159†
Between storage periods	1.3718	9	0.1524*
Error	1.3458	27	0.0498

* Denotes significance at 5 per cent level.
† Denotes significance at 1 per cent level.
S.S. Sum of squares.
D.F. Degrees of freedom.
M.S. Mean square.

TABLE 4. ANALYSIS OF VARIANCE OF THE RATE OF DESTRUCTION IN MIXED STRAINS OF FAECAL STREPTOCOCCI SUBJECTED TO FREEZING AND FROZEN STORAGE

(A) *S. durans* no. 1133 + *S. faecalis* var. *zymogenes* no. 1143, percentage of *S. durans*

Source	*S.S.*	*D.F.*	*M.S.*	*Source*	*S.S.*	*D.F.*	*M.S.*
Total	4.1767	15		Total	1623.3785	15	
Between blocks	3.9377	1	3.9377†	Between blocks	1308.0880	1	1308.0880†
Between storage periods	0.2168	7	0.0310†	Between storage periods	117.1687	7	16.7384
Error	0.0224	7	0.0032	Error	198.1218	7	28.3031

(B) *S. faecalis* no. 1136 + *S. faecalis* var. *liquefaciens* no. 309–2 percentage of *S. faecalis* var. *liquefaciens*

Source	*S.S.*	*D.F.*	*M.S.*	*Source*	*S.S.*	*D.F.*	*M.S.*
Total	19.0419	26		Total	5491.8563	17	
Between blocks	17.1733	2	8.5867†	Between blocks	4797.8453	2	2398.9227†
Between storage periods	0.6655	8	0.0832	Between storage periods	330.1363	5	66.0273
Error	1.2031	16	0.0752	Error	363.8747	10	36.3875

* Denotes significance at 5 per cent level.
† Denotes significance at 1 per cent level.
S.S. Sum of squares.
D.F. Degrees of freedom.
M.S. Mean square.

TABLE 5. ANALYSIS OF VARIANCE OF THE RATE OF DESTRUCTION OF INDIVIDUAL STRAINS OF FAECAL STREPTOCOCCI + COLIFORM SUBJECTED TO FREEZING AND FROZEN STORAGE

(A) *S. faecalis* + *E. coli* type I

Source	*S.S.*	*D.F.*	*M.S.*
Total	202.2634	47	
Between blocks	1.3667	3	0.4556
Between storage periods	39.3566	5	7.8713†
Between strains of bacteria	122.9399	1	122.9399†
Blocks × storage periods	3.3111	15	0.2207
Blocks × strains of bacteria	3.0292	3	1.0097*
Storage periods × strains of bacteria	29.2494	5	5.8499†
Error	3.0105	15	0.2007

(B) *S. faecalis* var. *liquefaciens* + *E. coli* type I

Source	*S.S.*	*D.F.*	*M.S.*
Total	224.0044	47	
Between blocks	2.2478	3	0.7493†
Between storage periods	35.3214	5	7.0643†
Between strains of bacteria	157.6824	1	157.6824†
Blocks × storage periods	0.2274	15	0.0152
Blocks × strains of bacteria	1.8094	3	0.6031†
Storage periods × strains of bacteria	26.4512	5	5.2902†
Error	0.2648	15	0.0177

(C) *E. freundii* type I + *S. bovis*

Source	*S.S.*	*D.F.*	*M.S.*
Total	321.5045	47	
Between blocks	0.7747	3	0.2582*
Between storage periods	36.5533	5	6.3107†
Between strains of bacteria	164.3117	1	164.3117†
Blocks × storage periods	1.2379	15	0.0825
Blocks × strains of bacteria	0.8903	3	0.2968*
Storage periods × strains of bacteria	26.6117	5	5.3223†
Error	1.1249	15	0.0750

(D) *A. aerogens* type I + *S. bovis*

Source	*S.S.*	*D.F.*	*M.S.*
Total	234.7982	47	
Between blocks	0.4934	3	0.1645*
Between storage periods	38.3502	5	7.6700†
Between strains of bacteria	167.9357	1	167.9357†
Blocks × storage periods	0.4169	15	0.0278
Blocks × strains of bacteria	0.5002	3	0.1667*
Storage periods × strains of bacteria	26.5812	5	5.3162†
Error	0.5206	15	0.0347

(E) *E. coli* type I × *S. faecium*

Source	*S.S.*	*D.F.*	*M.S.*
Total	246.8841	47	
Between blocks	3.0624	3	1.0208
Between storage periods	38.3502	5	7.6700†
Blocks × storage periods	0.9423	15	0.0628
Blocks × strains of bacteria	1.1245	3	0.3748*
Storage periods × strains of bacteria	38.5224	5	7.7045†
Error	1.2884	15	0.0859

(F) *S. faecalis* + *E. coli* type II

Source	*S.S.*	*D.F.*	*M.S.*
Total	182.6562	47	
Between blocks	6.6443	3	2.2148†
Between storage periods	52.2341	5	10.4468†
Blocks × storage periods	1.6506	15	0.1100
Blocks × strains of bacteria	11.5830	3	3.8610†
Storage periods × strains of bacteria	40.7046	5	8.1409†
Error	2.0277	15	0.1352

(G) *S. faecalis* var. *liquefaciens* + *E. coli* type I

Source	*S.S.*	*D.F.*	*M.S.*
Total	163.2306	47	
Between blocks	9.1687	3	3.0562†
Between storage periods	44.2459	5	10.8492†
Between strains of bacteria	42.1129	1	42.1129†
Blocks × storage periods	1.8120	15	0.1208
Blocks × strains of bacteria	9.7433	3	3.2478*
Storage periods × strains of bacteria	44.3820	5	8.8764†
Error	1.7658	15	0.1177

* Denotes significance at 5 per cent level.
† Denotes significance at 1 per cent level.
S.S. Sum of squares.
D.F. Degrees of freedom.
M.S. Mean square.

TABLE 6. ANALYSIS OF VARIANCE OF THE RATE OF DESTRUCTION OF MIXED STRAINS OF COLIFORMS + FAECAL STREPTOCOCCI WITH THE NATURAL FLORA OF PRAWN SUBJECTED TO FREEZING AND FROZEN STORAGE

Source	*S.S.*	*D.F.*	*M.S.*
Total	138.9313	27	
Between strains of bacteria	99.0621	1	99.0621†
Between storage periods	30.5620	13	2.3510*
Error	9.3072	13	0.7159

* Indicates significance at 5 per cent level.
† Indicates significance at 1 per cent level.
S.S. Sum of squares.
D.F. Degrees of freedom.
M.S. Mean square.

freezing and subsequent storage at low temperature, *S. durans* cannot probably be taken as an index of sanitation as its presence is only in very small numbers constituting less than 5 per cent of the total *Streptococci* in the product. On the other hand, *S. faecalis* var. *liquefaciens* may be taken as an index due to its higher natural incidence of 40 to 55 per cent as its rate of reduction during storage was found to be non-significant at 5 per cent level when present in combination with other strains. This organism thus stands out in its behaviour during freezing and frozen storage with its higher percentage of occurrence in frozen fishery products and can definitely be considered as a better index than any other organism.

The relative non-dependability of *E. coli* or other members of the coliform groups as indices of sanitation gets further support from the data on the rate of destruction of these organisms (as represented in fig 1). The counts of all the coliform organisms studied come down to nil within 60 to 90 days of storage. In the case of individual strains of *Streptococci* on the other hand (fig 2) although reduction was observed, these are never full as in the case of *E. coli*, the maximum destruction during freezing being only 55 to 60 per cent of the total count. Continued frozen storage does not affect the count very much and it is observed that more than 30 to 46 per cent survive even after one year. *S. faecalis* LMB_2 is, however, an exception where the reduction has been found to be about 92 per cent in one year.

Acknowledgements

The authors are indebted to Dr. A. N. Bose, Director, Central Institute of Fisheries, for his valuable advice and suggestions during the course of this investigation. They are also indebted to the Robert A. Taft Sanitation Engineering Centre and the National Type Culture Collection Centre (London) for making available the strains of faecal streptococci and coliforms respectively.

The authors wish to express their thanks to Shri T. S. Gopalakrishna Iyer for the technical assistance rendered and to Shri H. Krishna Iyer for the statistical analysis of the data.

References

FISHER, R A and YATES, F 1957 *Statistical Tables for Biological, Agricultural and Medical Research* (5th ed.), Oliver and Boyd, London.

HESS, E 1934 *J. biol. Bd Can.*, **1**, 95.

KENNER, B A 1961 *Appl. Microbiol.*, **9**(1).

KURELUK, K and GUNDERSON, M F 1959 *Ibid.*, **7**, 327.

LARKIN, E P, LITSKY, W and FULLER, J E 1955 *Ibid.*, **3**, 102.

LEKSHMY, A 1964 *Fishery Technology*, **1**(2), 143.

LUYET, B J and GEHENIO, P M 1940 *Biodynamics*, **3**, 33.

RECORD, B A and TAYLOR, R 1953 *J. gen. Microbiol.* **9**, 475.

SQUIRES, R W and HARTSELL, S E 1955 *Appl. Microbiol.*, **3**, 40.

WOODBURN, J M and STRONG, D H 1960 *Ibid.*, **8**, 109.

DISCUSSION

Kreuzer (FAO): In the past we have often considered the fact that fish taken by trawling frequently die in a state of exhaustion, in which case *rigor mortis* sets in earlier and is not so severe and the fish do not keep very well on ice. Now we hear that in some instances, fish that are well fed and not exhausted do not make as good a frozen product as starved or exhausted fish. It is evident that the conditions relating to the catching and first handling of fish are very important and very complex. Must we now change views regarding the handling of fish that is to be frozen?

Love (U.K.): In their paper, Dyer and Peters mentioned that they do not know of any work where a frozen fishery product has been quality tested as it passed through commercial channels. Robertson and Love (1965) tested consumer packs of frozen cod muscle taken from more than 70 shops over the North of Scotland, and compared them with the corresponding wholesale products (three brands) at the start of distribution. In only three cases was the quality of the retail packs, as tested by the cell fragility method, indistinguishable from that of the wholesale packs, and in about half, the readings were right at the bottom of the scale and the fish were very tough to eat. The results were not surprising in the light of a survey of the temperatures of retail cabinets carried out by the Humber Laboratory of Torry Research Station a few years previously. This showed that the temperature of many cabinets was well above −18°C (0°F), so that measurable deterioration would occur in a few days.

Symons (U.K.): I would like to stress the importance of the oxygen permeability of the packaging material in vacuum packaging and would like to know which packaging gives sufficient protection against the ingress of oxygen?

Banks (U.K.): I don't know that I'm a complete authority on this, but speaking purely from memory, I think we found that nylon 11 was reasonably effective and that certainly the laminates even more so. Of course the foil itself is the ultimate but it is, of course, too expensive for use. Has any other delegate here had experience in the case of the actual plastics in vacuum packing to prevent rancidity, or in the use of any of these other coatings such as the alginates and special glazes?

Symons (U.K.): I have direct experience of the use of alginates on frozen whale meat where—though the cost was high—the coating of slices of meat proved to be an excellent safeguard against rancidity.

Love (U.K.): The unusually poor performance of the cell fragility test reported in Connell's paper was the result of unknowingly using a formaldehyde solution of high pH. It subsequently transpired that the optical density values obtained by this method are reduced, so narrowing the working scale, if the pH of the diluted formaldehyde solution varies much above or below a value of 3.8. Unfortunately, when Connell's samples were tested, we used a batch of formaldehyde which had an unusually high pH, and the new factor was only identified after the completion of the experiment, with the unfortunate results already mentioned. However, in the instructions for the commercial model of this apparatus, we have now specified the pH to which the formaldehyde should be adjusted. It has already been shown that the scatter of results by the original cell fragility apparatus was less than that of protein extractability; the new modification, coupled with slightly more active homogenization, ensures a longer scale of values and hence greater sensitivity.

Connell (U.K.): I have to thank Love for his explanatory note about the cell fragility values quoted in my paper. He mentioned the relative sensitivity of the protein extractability and cell fragility methods. To compare the real sensitivity of the two methods, it would be necessary to carry out an equal number of measurements using both methods and I am not sure that this precise experiment has been carried out. Judging from the published results, I would expect that, if such a precise comparison were made, the sensitivity of the two methods would not be particularly different.

Love (U.K.): A comparison of the results of cell fragility and protein extractability determinations on cod stored at four different temperatures was published some time ago. The same fish were used for both determinations, and the experimental points for cell fragility showed much less scatter than those of the other method.

Jones (U.K.): With reference to Connell's paper, it does occur to me that some of the flavour changes characteristic of early chill storage may have occurred in his two-day fish as an artifact of the thawing and examining techniques where, as I understand, the material was thawed and left overnight prior to tasting. I take the point that may be made that this may relate to commercial practice.

The experimental arrangement reported, in which the fish were collected, iced and frozen over a considerable period of time and then examined within a few days has undoubted advantages in terms of the examination of widely varying material together. By comparison, the conventional approach is that the storage properties of individual catches of fish are sampled sequentially, and seasonal variations, etc., are examined by comparison of catches. It does appear that a number of factors, inherent in variability of catches, etc., may be observed by the method employed in the data reported by Connell. Among these is probably the breakdown of nucleotides and the production of hypoxanthine. There is considerable evidence that this does occur at temperatures in the region of $-14°C$ ($+7°F$).

Love (U.K.): Miss Kelly has presented a very interesting paper. The next step, I feel, is to try and establish the exact role of pH in the changes in the biological condition of the fish. We know enough (Love, 1967, this Conference) to be certain that it is related closely to the amount of depletion suffered by the fish. Thus a high pH fish contains less protein in the muscle, and we would therefore expect that the cross-linking of protein molecules, which probably leads to toughness, occurs less readily if the structural protein molecules are less numerous. From this point of view, the low pH-tough fish are more desirable as food, since they are richer in protein.

However, the relationship is not completely straightforward. In cod, the water content of the muscle is also a very sensitive guide to nutritional condition, rising as depletion proceeds. The material collected in our Iceland–Norway trip in 1965 and Iceland–Greenland trip in 1966 showed a trend in complete agreement with that reported in Miss Kelly's paper. Small cod nearly always had a high ultimate pH, while the pH of large cod could be high or low. However, the water contents of the same fish show no such trend, and we must therefore proceed further to show which parameter follows depletion the more closely.

Tomlinson (Canada): In connection with Love's remarks regarding the depletion of fish muscle as a result of starvation, we have some observations with sockeye salmon that may be of interest. These fish do not usually feed during their spawning migration and their flesh eventually becomes very greatly depleted. Now, we have found that if these fish are held in captivity during this period they will in fact feed very heavily, but whether they do so or not their flesh becomes equally depleted. This depletion thus seems to be related to sexual development rather than starvation.

Sutton (U.K.): I would like to comment on Love's statements concerning the relationship between pH and muscle water content.

We have considerable evidence to show that the extracellular space in cod muscle increases with water content, i.e. with starvation (Sutton, *J. Comp. Biochem. Physiol.* 1967, in press). Assuming that the pH of the extracellular fluid is similar to that of the blood plasma (pH 7.3–7.4) then as the fraction of extracellular space increases, the muscle pH as a whole will be higher. This also accounts for the generally higher pH and softer textures in small cod, where the fraction of extracellular space will be greater than in larger fish.

The *post mortem* changes in pH due to breakdown of glycogen are super-imposed on the physiological pH of the muscle. If a drop in pH occurs, the actomyosin gel structure contracts as the isoelectric point of the proteins is approached, and fluid is exuded. Where a high pH is maintained, the gel remains in a swollen state with a high water content.

Kelly (U.K.): I might add that I also tried the cell fragility method in addition to the other tests I used to measure deterioration in my cold storage experiments. It was during these storage experiments that the effect of muscle pH on the cell fragility test was observed. I found no clear-cut trends shown with this test during cold storage, while other methods indicated deterioration. I therefore consider the cell fragility method unsuitable for measuring deterioration.

Dyer (Canada): In regard to Love's remarks on the relation between pH and condition of fish, while the original glycogen content is largely determined by condition, the pH of the processed fish or fillet will depend on the degree of glycolysis occurring *ante mortem* or *post mortem*. The degree of *ante mortem* struggle will determine the amount of lactate found at this stage. A prolonged struggle may allow some lactic acid to be removed from the muscle by the blood stream. Any remaining glycogen will be converted to lactic acid *post mortem*, the rate depending on conditions of handling and storage. These factors all will influence the pH of the product.

MacCallum (Canada): In segregating frozen fish for quality, our work on trap-caught cod would indicate that patterns in overall textural quality can be predicted by measuring the pH before cooking but for any individual fish it was not possible to assess overall texture statistically on the basis of pH measurement. However, it was possible to obtain statistical correlation, if the sample were assessed for only the toughness aspect of textural quality.

I would venture the opinion that Miss Kelly's paper on pH and textural relations provides a very good argument for those who advocate *pre-rigor* freezing at sea or ashore.

Miss Kelly's comments that 40 per cent of Newfoundland trap fish landings (considered over the whole season) have a pH below 6.4 (prior to freezing) is very interesting. Our scientific and technological investigations on the incidence and effect of low pH in these fish (as low as pH 6.1–6.2) have been reported in the following papers:

1. MacCallum *et al.*, *J. Fish. Res. Bd. Canada* **23**, 1063–1081 (1966).
2. MacCallum *et al.*, *ibid.* **24**(3) (1967).

Tomlinson (Canada): My remarks are directed to Miss Kelly. I would like to know something regarding the severity of the effects she finds to be associated with low pH in cod flesh in comparison with those we have observed in Pacific halibut. In halibut stored in ice, increasing losses in extractability of protein occur with decreases in flesh pH, and very severe gaping can develop in fish with a low flesh pH even when the flesh is chilled to near 0°C before the onset of *rigor*. Are these phenomena observed in cod at this temperature?

Kelly (U.K.): I have investigated ice storage of cod with different pH values. Texture differences between high and low pH fish were marked initially; with ice storage differences became less due to softening. The tougher, low pH fish improved in texture. One interesting point we observed was that flavour defects started to appear in high pH fish after nine days, whereas it took 12 days for these defects to appear in low pH fish. I have not investigated protein extractability changes during ice storage.

Banks (U.K.): I wonder how much texture as such is a deteriorative factor in frozen fish. Perhaps other delegates present may wish to comment on this particular question.

Connell (U.K.): I feel that the question of the relative importance to the consumer of the various characteristics of frozen fish such as texture and flavour is important and I have been trying to obtain some information concerning the matter. I have been giving an ordinary untrained consumer panel—in this case the captive consumers represented by the staff at Torry Research Station—samples of frozen cod and haddock which have been cooked, and attempting to find out what they think about the samples. The indications from this exercise are that this set of consumers pay considerably more attention to flavour than to texture. Many more consumers responded adversely to samples having cold storage flavours than to samples which were tough. A full description of this experiment will, I hope, be reported in due time, but I would stress that the findings will be applicable only to the set of consumers tested, only to the species examined and only to tasting conducted in the ways selected.

It would be helpful if we had more information about the particular quality factors in frozen fish products which really influence consumer acceptance, because then the orientation of research effort would be facilitated.

Guillot (France): Je me permets d'intervenir à un double titre comme bactériologiste alimentaire (1) et comme vétérinaire (2).

(1) Bien que le sujet à l'ordre du jour de la Session 6 comporte "les problèmes relatifs à la microbiologie des produits de la pêche", une seule communication de nos collègues de l'Inde nous a été présentée sur ce sujet. Dans sa communication, M. Jendrusch a fait allusion à un contrôle "de routine", concernant la recherche des coliformes, staphylocoques et entérocoques, mais sans précision d'ordre quantitatif. Nous savons tous les difficultés d'établissement de normes bactériologiques pour les produits alimentaires, mais je pense qu'une enquête internationale auprès des divers laboratoires chargés du contrôle de salubrité des produits de la pêche congelés, surtout des produits préparés ou transformés (filets, "fishsticks", hachis) pourrait faciliter la tâche des organismes responsables de l'établissement de telles normes tant sur le plan qualitatif que quantitatif.

(2) Ces normes bactériologiques compléteraient si possible celles d'ordre biochimique concernant notamment les limites admissibles de la teneur en Azote basique volatil dans les produits de la pêche congelés, auxquelles notre confrère vétérinaire allemand, U. Kietzmann, a fait allusion dans sa communication. En France, ces limites ont été fixées, selon les espèces, par le laboratoire des Services Sanitaires Vétérinaires de Paris, qui recherche également la présence eventuelle d'histamine dans la chair des poissons congelés riche en histidine, tels les thonidés.

J'approuve entièrement la proposition formulée dans la séance précédente par notre confrère du Sénégal Malick Dia, confirmée par l'intervention du représentant du *Codex Alimentarius*, souhaitant que, sous l'égide de la FAO, soient coordonnés tous les travaux relatifs aux normes de qualité des produits de la pêche congelés (ou aux recommandations) discutées sur le plan international, à Genève (OMS), à Paris (OECD), éventuellement à Bruxelles (Communauté européenne).

Alvarez de Meneses (Spain): Considero que limitar el tamaño de la malla haría las capturas más comerciales pues sólo se pescarían ejemplares adultos evitando los jóvenes y por consiguiente la despoblación de los caladeros.

Asimismo, se debe evitar el contacto del pescado con la madera de la cubierta de los barcos pues ésta facilita el cultivo bacteriano y no se logra extirpar por muchos lavados que se le den; por tanto, estos peces presentan un gran contenido bacterial.

Durante la faena de descabezar los peces pueden transcurrir 2–3 horas entre los primeros y los últimos; a la temperatura de cubierta, los últimos sufrirán mayor degradación que los primeros. Por lo tanto, no puede ser exacta la respuesta de los catadores para determinar si un pescado congelado lleva 2, 5 ó 10 días de almacenamiento pues depende de la gradación del olor, sabor, etc., e incluso se puede suponer que un pescado que lleve sólo 3 días almacenado resulta peor que otro que lleve 10, si éste fue trabajado mejor.

También se habló de que la degradación es mayor en los peces muy alimentados; sin embargo, sabemos que hay peces poco o mal alimentados de carne blanda y que son de mala calidad.

Varga (Canada): Bacteriological standards by nature have to be arbitrarily established as the result of objective evaluation of problem. Our experiences have shown that 250 faecal coliforms/100 g of fish is a reasonable objective. This standard is somewhat lower than that proposed for other meat products but it can be achieved by reasonable degree of fish plant sanitation.

Symons (U.K.): I would like to sound a note of caution about the rather loose way we have all been using the word "quality". This over-worked and often emotive word—like beauty—is largely in the eye of the beholder and seldom means precisely the same thing to different individuals. May I take the "quality" of cold-stored cod as an example? Various authors and contributors to this session have opined that multiple freezing leads to no texture differences; that an exposure to −9° to −12°C (+10° to +15°F) for one to two weeks leads to no appreciable texture differences but texture deterioration occurs after a month or so's further low temperature storage; that cod stored for 86 weeks at −18°C (0°F) was acceptable; that over half of the quick-frozen cod on sale in North Scotland is unacceptable while Sutton did not tell us to what Time

Temperature Tolerance (TTT) 1500 g corresponds on his textureometer. This situation is chaotic and there is an urgent need for far more collaborative work between laboratories, preferably all previously agreeing to use one reference standard. I would criticize every person I have listened to—except Connell—for not attempting to correlate his or her own "pet" method with enough other methods. Each method may have considerable artistic value but they are not going to contribute to science until we all mean the same thing when we say "quality". It is clear that there is a large difference between the attitude on either side of the Atlantic to cold store flavour and texture deterioration since little if any fish is stored at temperatures below −18°C (0°F) on the American continent while most fish in Europe is bulk cold stored at −29°C (−20°F). I would ask Americans and Canadians present, do they reckon we in Europe are wasting considerable sums of money on the capital cost of our very low temperature cold stores, or are they giving the consumer a lower quality quick-frozen fish product than in Europe?

Anderson (Canada): The desirability of low-temperature storage and transport of frozen fish has long been recognized in Canada.

In the past some storages maintained suitable temperatures while others did not. Very recently requirements for low-temperature storage have become mandatory. The pertinent section reads as follows: "Rooms in which frozen fish are stored shall be maintained at a temperature of −15°F or lower". At the same time a requirement for transport of frozen fish also came into effect. It reads: "Frozen fish, while under the control of a carrier, shall be kept refrigerated in such a manner that when fish is delivered at its destination, its temperature shall not have increased more than 10 degF from its temperature at the time it was loaded".

MacCallum (Canada): In response to Symons' enquiry about storage temperatures in Canada, I can report that present storage temperatures in Newfoundland are in the range of −20° to −29°C (-4° to −20°F). Factory owners are cognizant of Canadian Government regulations to the effect that storage temperatures be maintained at −26°C (−15°F) or lower in existing and in new plants.

Symons (U.K.): I would like to ask why the second piece of Canadian legislation which Anderson read to us specified an allowable temperature rise during transport instead of specifying a maximum product temperature. This draft as it stands discourages lower bulk storage temperatures and is diametrically opposed to the philosophy of TTT. My own approach to the problem of temperature control throughout the cold chain includes a step-wise concept; bulk cold stores (in which the quick-frozen food may spend months) operate at about −29°C (−20°F); distribution stores (in which the residence time is days or a week or two) operate at about −23°C (−9°F) which gives me an opportunity to deliver to the retailer or caterer at −18°C (0°F). This, I believe, is not only a sensible approach to containing the inevitable small rises in temperature, which are virtually inseparable from handling quick-frozen foods and is in accordance with the concept of TTT, but is cheap, since it is generally true that it is cheaper to allow temperature rises in small refrigerated spaces (like vehicles) and to extract any heat gain in large spaces (like bulk cold stores). The regulation referred to would legislate against my procedure.

Anderson (Canada): Fish inspection regulations in Canada are drafted following consultation and discussion with industry. The regulation on frozen transport requires that the temperature of the product shall not rise more than 10 degF (5.6 degC) while under control of the carrier.

The temperature requirement for frozen fish storage is −15°F (−26°C) or colder. If a definite temperature at destination were required it would be −5°F (−21°C). This would be to the disadvantage of fish which have a storage temperature colder than −15°F (−26°C).

On the other hand the carrier may argue that the fish was at higher than desirable temperature at the time of loading. It is possible, in some instances, that frozen fish may be removed from the freezer at a warmer temperature than storage temperature. In such instances the carrier has a very sound point.

The 10 degF (5.6 degC) rise in temperature concept was adopted to take care of such cases.

Danielson (Switzerland): By following discussions at this Conference one gets the impression that very much emphasis is put on the quality of the products during production and also on the different methods of assessing the quality.

It seems to me that we do not have the right relationship between the work done by the technologists and the results at the distribution end. I wonder what use there is in this work done at the fishing and processing level if the necessary measures are not taken in order to preserve the quality of the products in such a way that the product is satisfying to the consumers.

I have several times had the opportunity of studying the quality of the products in freezing cabinets and making an evaluation of the work done by myself and my colleagues. It is a shame to see how thoroughly the products—which have been produced with great care using all the modern techniques in order to check on quality in the moment of processing and which have left the factory in good condition—are being spoiled during distribution. A couple of years ago I made an investigation in one of the more advanced countries in Europe and I can assure you that 90 per cent or even more of the turnover of frozen products go through cabinets with a temperature varying from −6° to −14°C (+21° to +7°F). It is an extreme case if you find a cabinet with a temperature of −18°C (0°F) or lower. These cabinets which fulfil this requirement are the old fashioned cabinets with lids which you only find in the smaller shops. The more "modern" the cabinets are, the worse they are and quite honestly I feel that very little progress—if any at all—has been made during the past 10 years in improving the performance of the freezing cabinets.

No chain is stronger than the weakest link and I am afraid that quite a lot of efforts have been wasted in the past, and will be wasted in the future, if we cannot improve the conditions on the distribution side.

I would like to put forward a question: Is it not possible to make a freezing cabinet in which the temperature of −18°C (0°F) can be maintained and which satisfies the marketing people with a sufficiently big display surface. I am putting this question to the manufacturers of freezing cabinets and I ask these people to explain what their real problems are. If they are not present I sincerely hope that I can get the message through and get some reply back—resulting in better temperature conditions in our freezing cabinets in the future. Without improvements here, we cannot really benefit from the technological work done at the fishing and processing level.

Scott (New Zealand): Investigations relating to determination of quality by objective and subjective methods have been presented. Providing that the measure of end point relates to the commercial life of the product, and is reproducible, the measure of quality for all suitable end points can be expressed in "days of life". Furthermore, if a standard figure of, say, −20°C be chosen, then quality for constant or variable conditions can be expressed as "days at −20°C". This technique is used in the dairy industry in the form of accelerated

tests (e.g. hours of methylene blue at 37°C) or in the canning industry (e.g. F values at 250°F). I suggest FAO attempt to collate evidence on quality measurements and assist in developing a general measure of quality as described above, or some other form.

We should distinguish between quality at the start of storage and the loss of quality during storage. If quality loss during storage is expressed in "days", then the loss per unit time of storage is "days per day", which is dimensionless. This has many scientific advantages, one of which is that such a dimensionless constant is directly related to the biological constant governing the rate of deterioration at various temperatures of storage.

Slavin (U.S.A.): I would like to comment on two points: (1) objective tests and (2) quality changes during storage and marketing.

With regard to objective tests, I agree with Scott that uniform tests are needed to permit assessment of quality. It is necessary, I think, that different laboratories work together to develop suitable tests and discard unsuitable tests. It appears that many of the same tests studied over past years are still being investigated with very little progress. With regard to my second point, I agree with Danielson that quality loss in frozen fish is a serious problem. In the United States studies have been conducted on quality of retail samples of frozen fish reaching the consumer and it is much less than that desired. All of the changes, however, do not take place during storage or transportation. Some findings indicate about 50 per cent of the quality loss takes place as a result of using low quality fish and the remainder is due to bad storage, transportation and retailing.

Sørensen (Denmark): Quality of product is the quality when the consumer has it in his hand. Some packets lie for one, two or even three years in the cabinets, even though scientific evaluation of shelf-life of frozen fishery products indicates a shelf life of something like 6 to 10 months. This tremendous gap between how things should be done and what is in fact being done, is a serious matter. The "first in, first out" principle should be standard practice in cold stores and in retail cabinets. However, it has proven to be difficult to educate the employees in the shops to do the right thing and it seems increasingly difficult to have labour take responsibility in this regard. By far the biggest quality problem for the frozen fish industry today is the problem of educating these workers.

Early (U.K.): I should like to make brief reference to an extensive survey of commercial freezing practice in the United Kingdom which included the measurement of quality at various stages in the line from entry of the fish into the factory to the retailer. You will recall that Dyer said he knew of no such work. I shall limit myself to what has been given in our Annual Reports over the past three years since the results of the work will not be published in full. The freshness quality of fish purchased for freezing in Hull and Grimsby was found on the whole to be comparatively good and from the top end of the market. Fish was bought for freezing not only when there was a surplus. Observations on factory practice showed that, in some plants, there was excessive loss of freshness during processing prior to freezing. This was mainly caused by keeping whole fish and even fillets overnight, often without ice. We recommend that only the minimum amount of whole fish should be left well iced for processing early the next day and that fillets should never remain unfrozen overnight.

Observations of freezing and cold storage were made and here again shortcomings in practice were found. Factory operatives seem unaware of how quickly frozen products, especially small consumer packs, warm up and often expressed the opinion that so long as the product was hard their duties were being fulfilled! Port bulk storage practice was found good with most stores retaining at least −26°C (−15°F). Inland cold stores were not so good.

The really sad story, however, unfolded when we looked at the retail end of the chain; zero cabinet practice left a lot to be desired. I could tell some wonderful stories here. I think it was Kelly who said earlier in the Conference that he felt we were too worried about the initial quality of shore-frozen fish and that the real malpractices were on the part of the retailer. Certainly as far as shore freezing is concerned, I couldn't agree more that the retailer is the weak link in the frozen fish chain. We found very serious textural and flavour faults and cold storage odour. It is true that these faults could have been caused by bad practice from the time of initial cold storage, but from our very detailed observations throughout, we feel they are mainly attributable to poor management of so-called zero cabinets. We can better a previous speaker in the range of product temperatures observed. Temperatures as high as −1°C (30°F) and as low as −23°C (−10°F) were found. Something like 50 per cent of the samples were stored at a satisfactory temperature. I disagree with the statement that the newer cabinets were the worst offenders. We feel the BSI standard has improved design and all would be well if the apparatus was used correctly.

I might add that, in spite of what Connell has said about texture being less important in regard to consumer acceptances, we feel the texture of a high proportion of the samples examined would be repulsive to the majority of consumers. I doubt if his worst samples were as poor as much of the material on retail sale.

O'Sullivan (Ireland): Many of the technologists at the Conference have made a plea for a clearer definition of fish quality which would be helpful in future research into the factors influencing quality and in devising methods of measuring quality. In this whole area one must query whether the definition of quality should be entirely one for the technologist. Surely the consumer should be taken into account to a greater degree than through representation on a trained taste panel (which should, of course, in their essence, be used for rating or scoring product within an established set of quality criteria rather than for the determination of the criteria themselves). Before approaching a clear definition of quality, serious consideration should be given to establishing the criteria on which the consumer bases his quality assessment rather than basing our definitions primarily on what, after all, are in many cases, our own assumptions.

Sale (U.K.): A statement has been made that frozen fish is inferior and cheap. I wholeheartedly disagree as I am sure do many other people in this room. By the very nature of the extra processing it can never be cheap and as regards being inferior, I can only state that through the excellent work of Banks *et al.* of Torry who strongly advocated −30°C (−20°F) cold storage, a practice which we have always adhered to, we have been able to distribute quick-frozen fish via the distribution channel, which my colleague Symons has mentioned, to people who previously could not get good quality fish through normal wet-fish distribution. You have heard of some of the other problems that the many other scientists have worked on. The work of Little and his team for my own company have made it possible for us to give the consumer the quality that she requires. The growth statistics of the international frozen fish fillets production from the *Yearbook of Fishery Statistics* prove this.

Therefore I feel that at such an excellent Conference of this nature, at which we are all striving for quality, care should be taken not to make statements which could be misconstrued.

Quality Control of Frozen Fish in Modern Fish Industries

by H. Jendrusch

Quality control of frozen fish in modern fish industries

This paper describes a comprehensive system of quality control covering all stages of the production of frozen fish products.

To attain high levels of sanitation and product quality, as well as an economic return, "Nordsee" starts its quality control with the processing and freezing of fish aboard the vessel. The quality control system uses analytical and statistical methods to monitor the quality at time of landing (unloading control), during frozen storage (semi-finished goods control), during processing (production control) and at the time of despatch of the finished frozen products to the customers (finished goods control).

Contrôle de la qualité du poisson surgelé dans les entreprises modernes

La communication décrit un système complet de contrôle de la qualité couvrant toutes les étapes de la fabrication de produits de la pêche surgelés.

L'entreprise "Nordsee", désireuse de maintenir à un niveau élevé l'hygiène et la qualité de ses produits tout en assurant une bonne rentabilité, fait débuter son contrôle de la qualité au stade du traitement et de la congélation à bord ("Bordkontrolle"). Le dispositif fait appel à des méthodes analytiques et statistiques pour suivre la qualité au moment de la mise à terre (contrôle au débarquement), durant l'entreposage frigorifique (contrôle des produits semi-finis), durant la transformation (contrôle de la production), et à l'expédition des produits finis aux consommateurs (contrôle des produits finis).

El control de la calidad del pescado congelado en las industrias pesqueras modernas

Describe este estudio un amplio sistema de control de la calidad que abarca todas las fases de la producción de productos pesqueros congelados.

Para obtener elevados niveles de higiene y de calidad del producto, así como también beneficios económicos, la empresa "Nordsee" empieza su control de la calidad con la elaboración y congelación del pescado a bordo de la embarcación (control a bordo). El sistema de control de la calidad utiliza métodos analíticos y estadísticos para fiscalizar la calidad durante el desembarque (control durante la descarga), durante el almacenamiento frigorífico (control de los productos semielaborados), durante la elaboración (control de la producción) y en el momento de enviar a los clientes los productos congelados dispuestos ya para su consumo (control de los productos finales).

MODERN quality control methods offer comparatively easy and labour-saving ways and means of checking on quality at the various stages of production, enabling the factories to make adjustments even during the production process and thus eliminate failures and economical losses.

Government quality control

At the German fishing ports, up to now only fresh fish landings are subject to veterinary control. For sea-frozen fish and portions thereof sale by auction is not compulsory. Sea-frozen fish is, therefore, not subjected to government control. A law on fish hygiene and pertinent regulations covering inspection, grading and production hygiene is in the process of being drafted.

On the distribution side, hygiene regulations of the German states sufficiently guarantee quality and hygiene of fresh fish on its way from the factory to the consumer. The trade in frozen food, including sea-frozen and shore-frozen fish, is subject to "Leitsätze für tiefgefrorene Lebensmittel" (Anon., 1965b), which, apart from the technique of freezing and cold storage, deal mainly with the distribution of frozen fish.

"Nordsee" has voluntarily established an internal quality code for the production at sea and on shore, and has developed a procedure for the application of these standards to production both on board and ashore.

Hygiene and quality

Because of its high nutritive value, fish is a main item of the food industries, particularly in industrialized countries. Preservation of the quality of frozen fish, in particular, is a major concern of every progressive fishing industry.

Just as the cold chain is a means to prevent untimely deterioration, the "hygiene chain" is vital for the production of a high grade product and the maintenance of its sanitary quality between the boat and the customer. Cleaning and disinfection of processing rooms and storage rooms, of machinery and equipment as well as personnel hygiene, should be a matter of routine on all fishing vessels and in shore factories.

One measure necessary to attain this aim on the vessel is to have separate areas and separate personnel for the slaughtering and processing operations. This separation of the functions of deck and industrial personnel secures an optimum of working hygiene. Under the control of experienced foremen, a trained crew of fish workers takes care of the freezing of fish and fish portions.

All measures taken on board and subsequently in the factories aim at hygienic production of sound sea-frozen fish by eliminating all detrimental health-hazardous influences.

Range of products

The "Nordsee" range of fish products frozen at sea includes frozen, headless round fish, tunnel frozen fillets in plastic bags and vertical plate frozen fillet blocks. Both bone-in and boneless fillets are produced. Species such as cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), hake (*Merluccius merluccius*), saithe (*Pellachius virens*), redfish (*Sebastes* spp.), the flatfish species, herring (*Clupea harengus*), mackerel (*Scomber scombrus*) and

other prime fish are utilized. Fish not suitable for human consumption are processed in a fish meal plant aboard the vessel.

SHIP BOARD QUALITY CONTROL

Separate treatment of the problem of quality control in the factories seems to us to be of little value, since control of production on the vessel has to be used as the main basis for all subsequent controls in the factories. Quality control begins with the first stage of production on board. All quality requirements with exactly defined standards for sea-frozen material are agreed upon between the trawler department and the processing industry.

Production control on board checks a number of factors, as for instance, the presence or absence of parasites, pathological changes of texture, blood stains and bruises, skin, fins, guts, mechanical damages, extraneous material and bones (if applicable), time and temperature of freezing (freezing velocity should be 1 cm/h), the core temperature after freezing (about −25°C, −13°F), the proper packing and coding of products and their proper stowage in the ship's cold store (−28°C, −18°F), and maintains a continuous thermographic control of storage temperature.

The ship's name, the fishing ground, the date of trip and production, the species of fish and kind of product, are marked on the wax-lined overwraps of the semi-finished products (blocks), in order to guide the processing industry as to their disposition. Stowage in the ship's cold store is made according to a stowage plan so that palletizing can be planned for the conveyance to cold stores on shore after unloading.

On arrival in port, care is taken that unloading of the sea-frozen goods is performed carefully and without undue delay. Conveyor belts and elevators installed on our stern trawlers permit unloading at such a speed that the frozen goods do not sustain any rise in temperature which could affect its quality.

FACTORY CONTROLS

Subsequent to ship board control, the following factory controls for the examination of the quality of sea-frozen fish are deemed advisable:

(1) Unloading control.
(2) Semi-finished goods storage control.
(3) Production control (statistical quality control).
(4) Finished goods storage control.

The unloading control will be explained in detail below as applied to sea-frozen cod blocks (boneless), frozen in plate freezers. The principle of these controls is also applicable, with minor modifications, to other species of fish and their method of being processed.

Unloading control

During unloading, samples of sea-frozen blocks are drawn at random and examined according to the assessment of defects form (fig 1) and the quality evaluation form (fig 2).

From each trawler load, amounting to about 20,000 blocks on our modern trawlers, about 300 sample blocks (1.5 per cent), i.e. about every 70th block, are drawn by the unloading gang and set aside on special pallets. The number of samples to be drawn is determined by the ASQ (1960) regulations.

The control pallets are immediately forwarded to the factory for examination and preparation of the quality report. The quality report is made known to all crew members (captain, foreman, etc.) who are responsible for the quality of the sea-frozen fish, before the vessel starts on its next trip. The report is discussed with a view to the possible elimination of defects and their causes.

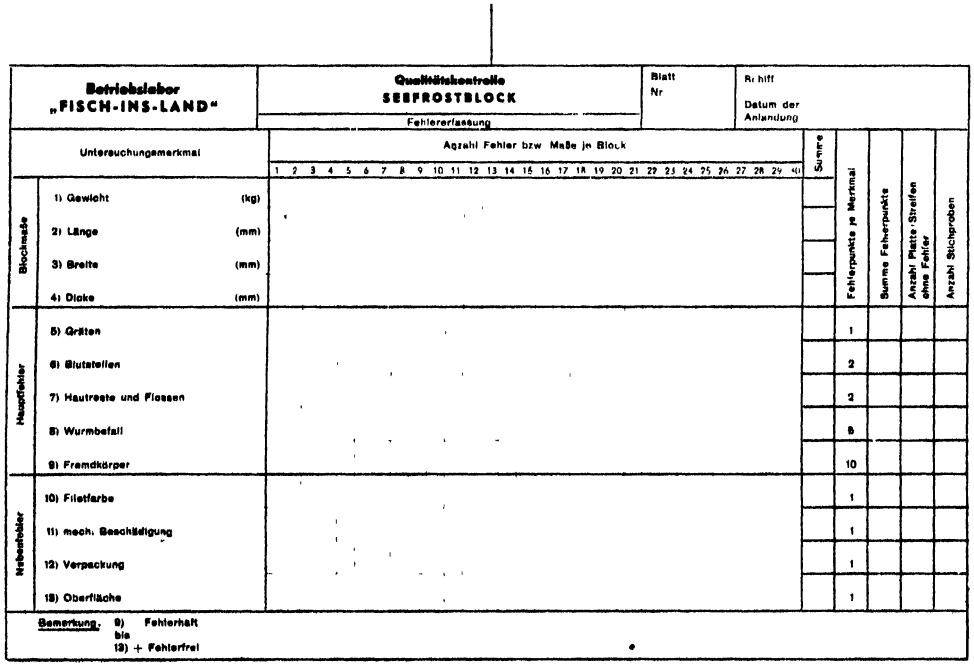
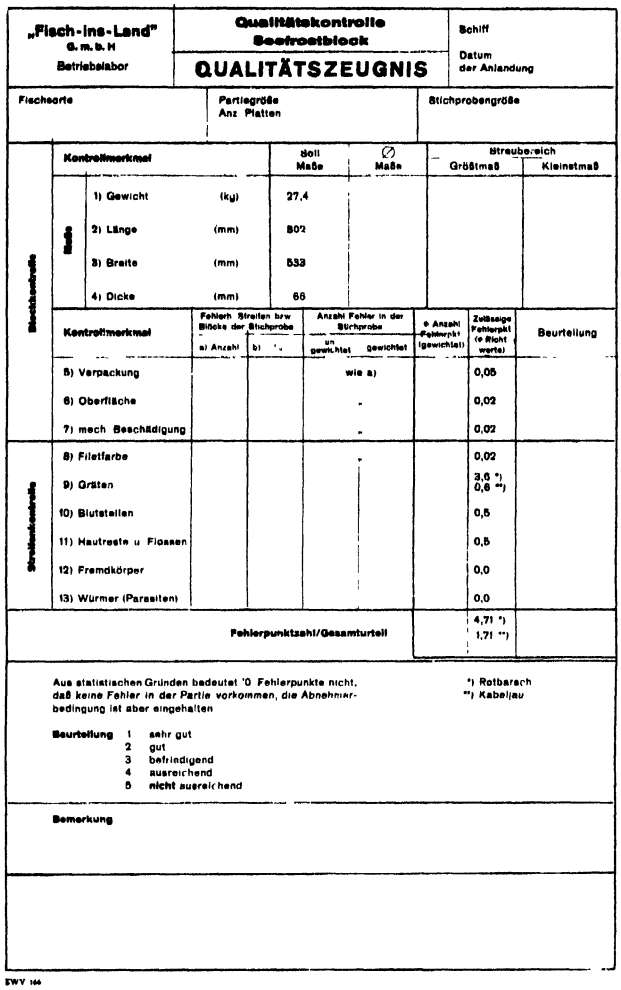


Fig 1. Form for assessment of defects of sea-frozen fish blocks



„Fisch-ins-Land" G. m. b. H
Betriebslabor

Qualitätskontrolle Seefrostblock

QUALITÄTSZEUGNIS

Schiff
Datum der Anlandung

Fischeorte | Partiegröße Anz Platten | Stichprobengröße

Blockkontrolle	Kontrollmerkmal		Soll Maße	∅ Maße	Streubereich Größtmaß	Kleinstmaß
Blöcke	1) Gewicht	(kg)	27,4			
	2) Länge	(mm)	802			
	3) Breite	(mm)	533			
	4) Dicke	(mm)	66			

Stichprobenkontrolle	Kontrollmerkmal	Fehler Streifen bzw Blöcke der Stichprobe a) Anzahl	b) "	Anzahl Fehler in der Stichprobe ungewichtet	gewichtet	∅ Anzahl Fehlerpkt (gewichtet)	Zulässige Fehlerpkt (∅ Richtwerte)	Beurteilung
	5) Verpackung			wie a)			0,05	
	6) Oberfläche			"			0,02	
	7) mech Beschädigung			"			0,02	
Streifenkontrolle	8) Filetfarbe			"			0,02	
	9) Gräten						3,0 *) 0,6 **)	
	10) Blutstellen						0,5	
	11) Hautreste u Flossen						0,5	
	12) Fremdkörper						0,0	
	13) Würmer (Parasiten)						0,0	
	Fehlerpunktzahl/Gesamturteil						4,71 *) 1,71 **)	

Aus statistischen Gründen bedeutet '0 Fehlerpunkte nicht, daß keine Fehler in der Partie vorkommen, die Abnehmerbedingung ist aber eingehalten

*) Rotbarsch
**) Kabeljau

Beurteilung 1 sehr gut
2 gut
3 befriedigend
4 ausreichend
5 nicht ausreichend

Bemerkung

SWV 166

Fig 2. Form for quality evaluation of sea-frozen fish blocks

Method of control. The whole block (about 24 kg) is first examined in respect of exterior appearance as, for instance, packing and uniformity of size. A destructive examination is made for the inspection of the interior of the block for blood stains, bones and parasites. For this purpose, sections of about 2.4 kg (765×482×63 mm) are sawn from the block, placed in bags and thawed. Before establishing this sort of control we had ascertained in a number of test series that the results of tests on such sections are representative for the whole of the block.

The thawed fillets and fillet pieces are examined for defects, and these are noted on a special control form. For internal use the different defects are expressed in score points, as for instance, 10 points for critical defects (extraneous material), five points for major defects (parasites), two points for moderate defects (pieces of skin, fins), and one point for minor defects (mechanical damages, bones).

An upper limit to the number of defects has been set. If this is exceeded, the product will be rated "substandard". Within the range of from zero to the upper limit, the product is rated "very good", "good" or "satisfactory".

A single occurrence of extraneous material or parasites will grade a product as "substandard", according to our internal quality standards. One bone or an aggregate of bones per 4 kg is considered to be the limit of acceptability.

If a block is graded "substandard" due to mechanical damages or improper fill (uneven surface), only the yield will be affected. After trimming the blocks, the quality of the finished product will not be affected.

If the packing is rated low, the storage time must be reduced in order to prevent dehydration, loss in texture, or contamination.

If the results of the block section examination are unsatisfactory, the control panel draws this fact to the attention of company management for a decision on the utilization of the blocks for some other purpose.

Semi-finished products—storage control

The sea-frozen blocks are placed in cold storage according to a stowage plan so that the goods can be taken out of storage for further processing on the "first in, first out" principle. The cold storage is routinely inspected as to proper stowage (distances between stacks, height). Temperatures are recorded thermographically. In the case of deviations in temperatures through breakdown or ice formation on the cooling coils, adequate measures, such as the use of reserve units, defrosting of evaporator (blast cooling), or transfer of goods to a different cold store, are taken immediately.

Production control (statistical quality control)

Statistical control pertaining to weight and quality requires a maximum effort in the factory. Only if both controls are effective can the quality of the products be safely determined. Products are only graded as good quality when both controls so indicate, i.e. both weight and commercial quality must not fall below certain limits set by our standards.

Compliance with these standards and a steady improvement in quality is the responsibility of the production control. They are furnished with a list of all products and their specifications, and all necessary details of production, so that they may guide the men in charge of factory control.

Product specification. The lists of specifications cover consumers' requirements for all "Nordsee" frozen products (breaded and unbreaded portions of various sizes, fish finger blocks, etc.). These lists contain in detail the specified requirements for such as:

(1) Sea-frozen semi-finished goods: species of fish, blocks, fillets in bags, etc.

(2) Finished products: components, size, weight, yield, description of special processing requirements as, for instance, breading, secondary freezing, defreezing, etc.

(3) Packing: individual packing, outer packing, shrink wrapping, foils, cartons, master cartons, interleaves, paper bags, plastic bags, linings (wax, etc.), closing and marking (printing, labelling, coding).

By using these specifications, the planning and control panels can check on all quality requirements for the products.

Weight control. The weight of all finished frozen products produced from sea-frozen fish are systematically controlled in order to guarantee compliance with legal or customers' requirements. The amount of weight control sampling depends on the susceptibility of the product to give reason for complaints regarding weight.

Points of controls and number of controls are determined by a control plan. The control panel is guided by the daily production orders which are drawn up by the production planning department. Controls are organized through a system of control cards (fig. 3).

With these controls, it becomes possible to narrow the range of weight variations, with due regard to the customers' requirements (tolerance) and consequently to lower the average weights and obtain better yields to the producer.

Commercial quality control. The commercial quality control checks on defects adversely affecting the saleability of a product.

The following is an example of commercial quality control as applied to cod portions, sawn from sea-frozen blocks.

Samples are drawn at a rate of 20 per hour (200 per day) and major and minor defects are entered on the commercial quality control card (fig 4). Major defects

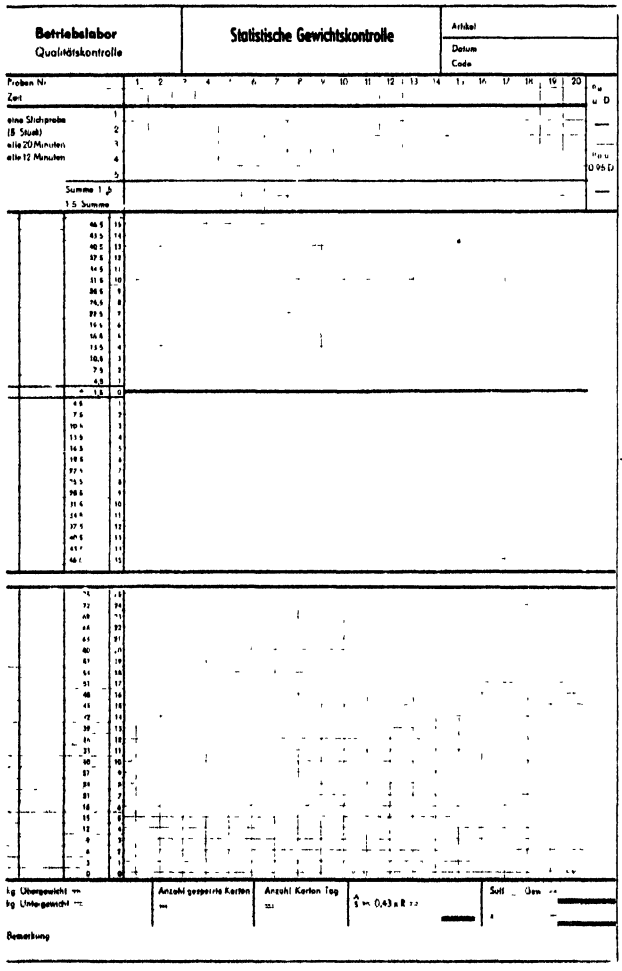


Fig 3. Statistical weight control of frozen fish products

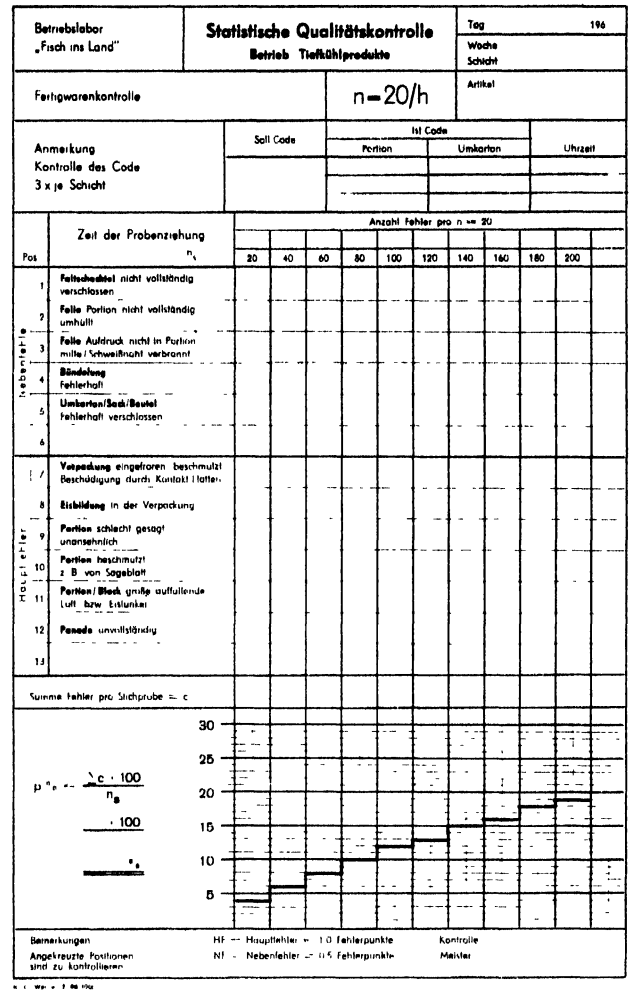


Fig 4. Form for statistical quality control of frozen fish products

influencing the saleability of the products are ice pockets in the pack, uneven size, contamination of portions, air pockets, uneven breading, damaged or contaminated packs. These are rated 1.0 point. Minor avoidable defects in outward appearance, such as packing (carton, foil, outer carton, bundling) are rated 0.5 point, i.e. two minor defects are equal to one major defect.

Most of our customers for frozen products from sea-frozen fish accept 5 per cent defects. A graduated limit is marked on the commercial quality control card identifying such samples whose average score of defects exceeds the 5 per cent limit.

The results of the daily weight and commercial quality controls are submitted to the foreman concerned and the factory management for attention.

The commercial quality control, which includes a continuous examination of the product for extraneous material using a metal-finder, has helped a great deal in eliminating defects.

Laboratory controls. Besides the above-mentioned production control cards, organoleptic, chemical and bacteriological controls are carried out in the laboratory.

The various daily products are submitted to a permanent test panel for blind-testing examination of the

thawed and cooked products according to the regulations of DLG—Qualitätsprüfung für Fishwaren (Anon., 1965a). This test panel assesses appearance, odour, flavour and texture of the products.

Chemical control uses volatile base nitrogen (VBN) (Antonacopoulos, 1965) as an index of quality in the finished products. Tests are made on samples taken at random, since repeated examinations of frozen portions have shown that the results are not changed as long as the cold chain is not interrupted and the storage time is not unduly extended.

According to our experience, the determination of VBN, in combination with the results of the organoleptic tests, is the only feasible way of determining the quality. Other time-consuming chemical methods for the determination of the quality of frozen fish products (TMA, VA, VRS, enzyme tests, etc.) do not satisfactorily correspond with the organoleptic ratings (Gould, 1965).

Bacteriological control is important to the freezing department since it indicates the state of compliance with sanitation and food hygiene standards.

This sort of control is, however, very difficult to integrate with the production schedule, since the results of tests are not available until after a lapse of two or three days. Nevertheless, all finished products are checked for bacterial count and hygienic quality. Tests for the presence of *Coliform*, coagulase-positive *Staphylococci* and *Enterococci* are made as a matter of routine. A study of the results of these tests, at frequent intervals, evaluates the sanitary conditions in the factory and indicates any necessity for remedial action.

Other ingredients, such as egg powder and breading flour, are examined on arrival at the factory and are released for use only after completion of bacteriological examination. Examination standards have been developed as a result of experience. Constant contact is maintained with the suppliers in order to ensure and improve the bacteriological quality of ingredients. Intensive bacteriological control is also maintained, according to a fixed schedule, at the different stages of production, particularly at those stages which are most exposed to hazards.

Since day codes are used, it is possible to investigate any grave production failures which may have occurred. Also, in cases of doubts or complaints, the goods in question can be subjected to the three above-mentioned controls which, taken together, provide a comparatively safe basis of assessment.

Finished goods storage control

The finished frozen products are conveyed to the finished products cold store which is controlled only with respect to proper stowage and temperature. The storage time here is short, as customers call for their orders for shipment either to inland points of sale or to inland intermediate cold stores. After the goods have left the factory's cold store, the responsibility for their quality rests with the customers.

CONCLUSIONS

It has not been possible within the frame of this report to go into all the details of quality control. The foregoing is only intended as a guide to the operation of controls which are practical under the existing organization and with the existing technical equipment of the factories, with due observation of well-known control criteria.

Quality has to be continuously controlled and cannot be left to chance, even in a highly efficient production. "The best definition of quality is that which the public like best" (J. Hammond, Cambridge/GB). Any decline of quality of frozen products at any stage of production will result in losses to the company and a poor relationship with the customers.

If controls are properly planned, a comparatively small number of people (about 4 to 5 per cent of the employees) can manage the quality control function and in cooperation with a trained staff can guarantee production of high quality frozen fish products.

Adequate sanitation, quality and efficiency are indispensable for the successful operation of a food factory, particularly in the fishing industry.

References

ANON. 1965a. Bestimmung zur DLG-Qualitätsprüfung für Fischwaren, Deutsche Landwirtschafts-Gesellschaft, Marktabteilung, Frankfurt/Main.

ANON. 1965b. Leitsätze für tiefgefrorene Lebensmittel, Bekanntmachung von Leitsätzen für das deutsche Lebensmittelbuch, *Bundesanzeiger*, 2 June 1965.

ASQ—STICHPROBEN-TABELLEN ZUR ATTRIBUTPRÜFUNG 1960. Deutsche Arbeitsgemeinschaft für statistiche Qualitätskontrolle (ASQ) beim Ausschuss für wirtschaftliche Fertigung e.V., Frankfurt/Main, Berlin, Beuth-Vertrieb GmbH, 2nd ed.

ANTONACOPOULOS, N. 1965. Methoden der Qualitätsbeurteilung tiefgefrorener Fischerzeugnisse, *Infn Fischw. Auslds*, **12**, 180.

GOULD, EDITH 1965. *Testing the Freshness of Frozen Fish*, Fishing News (Books) Ltd., London.

Evaluation of Quality of Frozen Fish and Fish Portions

by U. Kietzmann

Evaluation of quality of frozen fish and fish portions

The paper discusses the measures for quality assessment and control of frozen fish that are considered sufficient for the type of inspection for which an official veterinarian, who has a laboratory at his disposal, is responsible. Three techniques are regarded as being necessary and effective for this purpose. These are the determination of volatile basic nitrogen, the measurement of moisture loss following thawing and cooking, and the evaluation of quality of both raw and cooked fish by a taste panel. A brief description of the methods used is given in the paper.

Evaluation de la qualité du poisson congelé entier et en portions

La présente communication analyse les méthodes d'évaluation et de contrôle de la qualité du poisson congelé que l'auteur juge suffisantes à assurer le type d'inspection dout un vétérinaire disposant d'un laboratoire a la responsabilité. Trois techniques sont nécessaires et efficaces à cette fin: la détermination du taux d'azote alcalin volatil, la mesure de l'exsudation en cours de décongélation et de cuisson et l'évaluation de la qualité du poisson cru et cuit par un groupe de dégustateurs. La communication contient une description rapide des méthodes utilisées.

Evaluación de la calidad del pescado entero y troceado congelados

El autor examina las medidas de determinación y control de la calidad del pescado congelado que se consideran suficientes para la clase de inspección que realiza un veterinario oficial que dispone de un laboratorio. Con este fin son necesarias tres técnicas: la determinación del nitrógeno básico volátil; la medición de la pérdida de humedad debida a la descongelación y cocción; y la evaluación de la calidad del pescado crudo y cocido por un grupo de degustación. Se describen brevemente los métodos empleados.

SINCE 1900 world fish landings have increased about 10 times while the world population has doubled. It is the responsibility of the authorities concerned with food hygiene to watch the future development of fish supplies and to ensure that nutritionally important fish protein will be distributed without loss in quantity or nutritive value. To meet this responsibility, it is essential to acquire information on factors affecting the nutritive quality, to measure quality changes and to develop appropriate quality standards.

In Germany, non-marketable fish or trash fish consisting of fish that are too small or are not palatable, such as horse mackerel (*Caranx trachurus*) and sand launce (*Ammodytes tobianus*) are reduced directly to fish meal. In this connection, it may be mentioned that fish which is reduced to fish meal will also eventually add to human nutrition.

Freezing is, at present, one of the most important methods of the preservation of food fish. For practical reasons most species of fish are evaluated and only the edible portions preserved by freezing. Very large fish such as tuna (*Tuna* spp.), porbeagle (*Lamna nasus*) and expensive fish such as salmon (*Salmo salar*) and sea trout (*Salmo trutta*) are, however, generally frozen as whole fish. Flat fish and fish that require further processing such as herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) are also frozen in the whole. Freezing fish on shore is, at present, less important in Germany than freezing at sea.

The quality assessment of freezing fish products is based on the quality criteria for fresh fish of the same species. It is therefore very useful, both in the training of the examiner and for the clarification of doubtful cases, to make comparisons between the frozen product and fresh untreated fish of the same species.

Well-known scientific investigations, as well as our own experience, suggest that it is easier to judge frozen fish and observe the expected signs of deterioration if they are separated for inspection into lean and fatty species. This is because fat oxidation is not eliminated at the temperatures commercially used in cold storage. It seems doubtful whether fat oxidation which is of a chemical nature can be retarded by cold under practical conditions to the extent that it would not be commercially significant. The difference between lean or fatty fish is so important that they should be identified as such on the packaging at time of freezing. Although this appears to be a very simple matter, it has not been done to any great extent in spite of economic losses such as those involved in complaints concerning frozen redfish (*Sebastes* spp.) and herring.

It is also important to mark the processing date (week of processing) on the packaging of frozen fish products. This information is essential for the estimation of the storage time and for decisions concerning the final utilization of the frozen products so that economic losses will be avoided.

In freezing fish, due attention must be given to several important factors which influence the quality of the raw material. The time between catching and *rigor mortis* is important since research results suggest that fish should be frozen before resolution of *rigor mortis*. The development of *rigor mortis* varies with different species and may also be related to the fishing method. According to research findings of Partmann (1963) and our own investigations, the period before resolution of *rigor mortis*

is, from the point of view of quality, better than any other time for freezing fish.

Another factor of great importance to the quality of the frozen product is the influence that slaughtering and bleeding has on the colour of the fish flesh. The colour of the flesh of fish bled before freezing compares more favourably with the flesh of the fresh, non-treated fish than does the colour of the flesh of non-bled fish. Filleting immediately after catching seems to be the only solution with regard to the bleeding of redfish and herring. There are, of course, problems on board fishing vessels, especially when big hauls come on deck, but filleting on board is obviously the only way to avoid the discolouration of herring flesh.

Based on extensive comparative research by Partmann, the most favourable freezing speeds and temperatures relative to economy and techniques are such that a minimum core temperature of −15°C (5°F) is reached in 2 h. A storage temperature of −28°C (−8°F) is considered most favourable. It is absolutely essential for the quality control of frozen fish that the storage temperature be controlled. As a matter of economic interest thermograph records should be required in future in the inspection of all large lots of frozen fish stored in warehouses. Since it is possible to check pasteurization temperatures in dairies and regulate the temperature of heating processes by means of a thermograph, the installation of this necessary equipment should also be required for cold storage rooms in which frozen fish is stored. Since the production of vital goods exceeds the bounds of private interests, the industry concerned must definitely overcome its reluctance in regard to coding and temperature control.

In addition to the examination of thermograph records, the submission of which should be made compulsory for quality control of large lots of stored frozen fish, the official veterinarian, in order to evaluate the present condition, should take core temperatures with an electric thermometer. These instruments make it possible to take a number of temperatures and obtain a representative average very quickly. Such measures are necessary because of the temperature fluctuations occurring in large cold stores due to loading and unloading of the rooms.

Maintaining a constant temperature is very important because, even at a low temperature of −20°C (−4°F) a small amount of water remains liquid in the cell tissue where it completely freezes only at a temperature of −72°C (−97°F). Fluctuation of temperature between −12° and −30°C (+13° and −22°F) may increase the amount of unfrozen liquid and, as the temperature decreases, cause it to precipitate in the form of ice crystals to the detriment of the frozen food. Temperature fluctuations also cause increased evaporation.

Partmann has shown that the loss of energy-rich, unstable phosphate in the form of adenosine 5-triphosphate (ATP) and adenosine 5-diphosphate (ADP), the content of which decreases in any case by about one half due to enzymatic breakdown during freezing, may be prevented or decreased only at temperatures of −20°C (−4°F) or lower. The role which ATP and ADP, as well as inosine 5-monophosphate (IMP), their last decomposition stage, may play as quality component in fish flesh, is unknown. It is suggested that they may be important for maintaining the species-specific aroma. Our own experiments have shown that there is a decrease in the positive flavour scores with decreasing amounts of phosphates, and when they disappear, flavour assessment results in low value scores.

The official veterinarian must also consider whether the packaging material used will have any adverse effect on the frozen food. The packaging of frozen fish is important also from the food-hygiene point of view. The fish are frozen aboard the freezer trawlers in blocks of 5.6, 10.5 and 27 kg (12.3, 23 and 60 lb) and stored. The packaging serves the following purposes:

(1) It protects the surfaces from damage by using flexible corrugated paper.
(2) It prevents the blocks from freezing to each other.
(3) It prevents evaporation.
(4) It protects, to a limited extent, the frozen fish from light exposure, thereby preventing photochemical oxidation and colour changes.
(5) It provides a surface for labelling the fish blocks as to species, freezing time and with other information required for quality control in order to take into account quality changes which may occur on fishing trips of several months' duration.

Attention must be given to temperature rises during unloading of the frozen fish. Increases of 10 degC (18 degF) in temperature have been observed in freely-exposed blocks during summertime. We suggest that appropriate technical measures should be developed to protect frozen fish during unloading. Closed containers or mechanically-cooled tunnels could be used.

The following tests should be used to assess the quality of frozen fish.

(1) The determination of volatile basic nitrogen, by Antonacopoulus' method: This method is a modification of the process used by Lücke and Geidel (1935) in which ammonia, trimethylamine and dimethylamine are separated from the homogenized substance by means of steam distillation.

(2) The measurement of moisture loss following thawing and cooking: Knowledge of this moisture loss allows us to draw conclusions as to processing techniques and the potential quality of the frozen fish for further processing. The "Deutsche Landwirtschafts-Gesellschaft Bestimmungen 1965" (specifications) should be used without reservation for this evaluation of quality.

A moisture loss of up to 22 per cent is regarded as favourable; 22.1 to 25 per cent moisture loss is considered good, and 25.1 to 28 per cent satisfactory (neutral). I would consider moisture losses of over 28 per cent tolerable only where other characteristics indicate the quality to be particularly good.

(3) An organoleptic test following the system outlined below: The test is carried out by several trained people and assesses appearance and physical characteristics, as well as the odour and flavour of the fish in the raw and cooked states. I suggest that two rough estimates be made at the beginning of every organoleptic test: "pleasant" and "unpleasant". To break these categories down further, quality may be assessed according to the following scoring system:

		Points
Odour	Pleasant, specific	4
	Insipid, flat	3
	Fishy, musty	2
	Putrid, ammoniacal	1
	Pungent, putrid	0
Texture	Firm, slightly elastic but not tough or rubbery; moist but not mushy;	5
	Moderately firm; only slightly tough or rubbery; does not feel stringy in the mouth; moist but not mushy;	4
	Moderately tough or rubbery; tends to be noticeably stringy in the mouth, or is dry or mushy;	3
	Tough or rubbery; tends noticeably to form stringy mass in mouth, or is very dry or very mushy;	2
	Unpleasantly tough, rubbery, dry or mushy;	1
Flavour	Very good, specific	7
	Good	6
	Average	5
	Slightly fishy	4
	More fishy, bitter (slightly)	3
	Strongly fishy, bitter	2
	Putrid, repugnant	1

In the light of the numerous investigations which resulted in these proposals for practical inspection, the following comments may be made.

The above-mentioned method of assessing quality is sufficient for the type of inspection for which an official veterinarian, who has a laboratory at his disposal, is responsible. In addition, it is possible to obtain scientifically exact information concerning fat oxidation, enzyme activity, texture, absorption of light and protein breakdown. Such determinations are, however, too complicated and time-consuming to be used for on-the-spot inspection.

With regard to the potential storage life of frozen fish, it can be said that the highest degree of freshness can be maintained eight to 10 weeks for lean fish and six to eight weeks for fatty fish if proper processing takes place before the complete resolution of *rigor mortis*. Frozen fish products can be expected to remain in good quality for approximately double the period of time, and there should normally be no justifiable complaints concerning quality during this period. If cold storage must be extended longer than this—say again for double the length of time—inspection requires great care and the number of samples necessary for quality assessment must be adjusted accordingly.

The scope of the problem has made it necessary to limit this report to the official veterinary inspection in sea ports.

References

Deutsche Landwirtschafts-Gesellschaft (DLG) Marktab-
1965 teilung, *Bestimmungen für die Qualitätsprufung für Fischwaren*, Frankfurt/Main.

LÜCKE, F and GEIDEL, W *Z. Lebensmittelunters., u. -Forsch.*,
1935 **71**, 441.

PARTMANN, W and GUTSCHMIDT, J Mitteilungen aus der
1963 Bundesforschungsanstalt für Lebensmittelfrischhaltung. *Kältetechnik*.

A Taste Panel Technique for Evaluating the Eating Quality of Frozen Cod

by C. R. Baines, J. J. Connell, D. M. Gibson, P. F. Howgate, Evelyn I. Livingston and J. M. Shewan

A taste panel technique for evaluating the eating quality of frozen cod

The final eating quality of frozen fish reaching the consumer will depend, in general, upon the sum of, or interaction between, the deteriorations occurring in both the unfrozen and frozen states of the fish throughout its history.

Detailed descriptions of the organoleptic changes occurring during unfrozen storage of fish are available, but similar comprehensive descriptions of the changes occurring during freezing and frozen storage are lacking. A new study is therefore being made of the changes in organoleptic characteristics of frozen fish, and taste panel score sheets based on the findings are being constructed. This study is confined to white fish, and to date only cod (*Gadus morhua*) has been surveyed.

It is now clear from this and previous work at this Station that two distinctive types of change of equal importance occur during frozen storage. These are changes in texture and flavour (including odour), and it has been found possible clearly to differentiate these changes from those occurring during ordinary chill storage. It has been established that the organoleptic characteristics described in the Shewan–Ehrenberg score sheet are not appreciably modified by frozen storage, and that the initial freshness does not affect the nature of the changes occurring during frozen storage.

Thus it is possible to score reasonably accurately any sample of frozen cod in terms of the deteriorations occurring during both the unfrozen and frozen stages of its history.

Méthode permettant aux jurys de dégustation d'évaluer la qualité à la consommation de la morue congelée

La qualité finale à la consommation du poisson sera généralement fonction de la somme ou de l'interaction des phénomènes de décomposition se manifestant aussi bien pendant l'état de non congélation que pendant celui de congélation.

On dispose actuellement de descriptions détaillées des changements organoleptiques qui se produisent au cours de l'entreposage du poisson non congelé, mais on manque de descriptions aussi complètes pour ce qui est des changements survenant au cours de la congélation et de l'entreposage du poisson congelé. On a par conséquent effectué une nouvelle étude sur les changements affectant les caractéristiques organoleptiques du poisson congelé et des feuilles de notes ont été établies sur la base des résultats obtenus par des jurys de dégustation. Cette étude a été limitée au poisson de chalut et jusqu'à présent la morue seule (*Gadus morhua*) a été examinée.

Il ressort clairement de cette étude, comme d'ailleurs des études précédentes effectuées dans cette station, que deux types de changements distincts, mais d'égale importance, interviennent au cours de l'entreposage à l'état congelé. Ces changements affectent la texture et le goût (y compris l'odeur) et il a été possible de les différencier nettement des changements survenant au cours de l'entreposage normal de réfrigération. Il a été établi que les caractéristiques organoleptiques décrites dans la feuille de notes de Shewan–Ehrenberg ne sont pas modifiées sensiblement par l'entreposage à l'état congelé et que la fraîcheur initiale n'affecte pas la nature des changements survenant pendant cet entreposage.

Il est donc possible de noter d'une manière raisonnablement correcte n'importe quel échantillon de morue congelée d'après la détérioration survenant aussi bien pendant l'entreposage à l'état congelé ou non.

Una técnica de equipo de catadores para evaluar la calidad comestible del bacalao congelado

La calidad comestible definitiva del pescado congelado que llega al consumidor dependerá, en general, de la suma de las alteraciones que se produzcan en el estado no congelado y congelado del pescado durante toda su historia, o de las acciones mutuas de aquellas alteraciones.

Se dispone de descripciones detalladas de los cambios organolépticos que ocurren durante el almacenamiento del pescado no congelado, pero faltan descripciones análogas de las variaciones que se originan durante la congelación y el almacenamiento del pescado congelado. Por esto se está realizando un nuevo estudio de los cambios en las características organolépticas del pescado congelado, y se están preparando hojas de puntuación para los equipos de catadores basados en los resultados. Este estudio se limita al pescado blanco y hasta la fecha sólo se ha examinado el bacalao (*Gadus morhua*).

Como resultado de este trabajo y de otro anterior realizado en esta Estación es evidente que durante el almacenamiento del pescado congelado se verifican dos clases de cambios distintivos de igual importancia. Estos cambios son los de la textura y el sabor (incluyendo el olor) y ha sido posible diferenciarlos con claridad de los que ocurren durante el almacenamiento refrigerado. Se ha observado que las características organolépticas descritas en la hoja de puntuación de Shewan–Ehrenberg no registran modificaciones sensibles con el almacenamiento del pescado congelado, y que la frescura inicial no influye en la naturaleza de los cambios que tienen efecto durante el almacenamiento del pescado congelado.

Así, pues, en cualquier muestra de bacalao congelado es posible indicar con bastante precisión las alteraciones que tienen lugar durante las fases no congeladas y congeladas de su historia.

A NUMBER of taste panel techniques for assessing the quality of unfrozen cod and other fish species have been described and are in use in different parts of the world. These techniques vary in objective and complexity but are of three main types. Firstly, there are those which categorize the fish on the basis of its acceptability for eating. Secondly, there are those which categorize the fish on the basis of well-defined characteristics which change during storage. Thirdly, there are techniques which include elements of both of these types. Techniques of the first type usually employ a single grading or hedonic (like-dislike) scale, whilst those of the second type employ descriptions of various characteristics. The most elaborate and highly developed technique of the second type is that described by Shewan *et al.* (1953) which has been in regular use for many years at Torry Research Station.

Taste panel techniques for frozen fish have been described in detail less frequently. In the main these techniques are based on acceptability or grading systems of scoring. Such systems have been described for frozen salmon (Heerdt and Stansby, 1955), herring (Anderson and Danielson, 1961), mackerel and herring (Liljemark, 1964), whiting (Peters 1963) and cod (Armstrong *et al.*, 1960). In these systems of scoring, the attributes of appearance, colour, flavour and texture are often, but not always, separately scored for, but changes in the

attributes are not described in detail. The system described by Dyer and Dyer (1949) uses scales incorporating descriptions of changes in several attributes of the fish as it deteriorates, and also a scale for grading the overall quality. Dyer and Dyer's system has been used extensively in the Halifax laboratory of the Fisheries Research Board of Canada to evaluate the quality of both unfrozen and frozen fish of various species. Another scoring system utilizing descriptions is that of Gutschmidt (1965) which is, however, confined to textural changes occurring during freezing and frozen storage. Scoring systems for textural changes have been mentioned by Kelly *et al.* (1966) and Cowie and Little (1966) but not described in detail. In addition to these scoring systems, use has been made of paired comparisons (Moorjani, Montgomery and Coote, 1960; Love, 1966) to detect changes in texture during frozen storage.

All these scoring systems for frozen fish are incomplete in that they either do not cover all attributes or fail to differentiate clearly between the different kinds of change which can occur separately whilst the fish is in the unfrozen and frozen states. In addition, in arriving at the final panel score, the scores given for various attributes are sometimes averaged, which could have the effect of obscuring a change in one attribute which was of overriding importance as far as acceptability was concerned (Ehrenberg, 1953). A comprehensive and detailed scoring system for frozen fish requires to distinguish between all the detectable changes in sensory attributes which might occur, and to keep the scores so obtained separate unless it could be shown they can be justifiably and meaningfully combined. It was the aim of the present study to construct such a scoring scheme for frozen cod (*Gadus morhua*); an account of a preliminary phase of this study has been published (Baines and Shewan, 1965).

EXPERIMENTAL

Preliminary considerations

Deterioration in the quality of frozen cod can occur at all stages in its history from death up to the point of eating. Included, in general, will be changes occurring in the unfrozen and frozen states, and in the stages of transition between these states, that is, during freezing and thawing when the fish is neither wholly unfrozen nor wholly frozen. It is necessary to include these stages of transition in any general treatment because deteriorations may occur in them which are uniquely different from those occurring in the entirely unfrozen or entirely frozen states. Such unique changes may assume some importance during, for example, very slow freezing or thawing. Although theoretically the deteriorations occurring in the transition states ought to be included in any completely general system of quality evaluation, they have not been covered in the present study because with modern practice freezing and thawing times are so short that unique deteriorations occurring during these processes can be effectively neglected. Of course, rapid freezing and thawing may produce their own "instantaneous" changes in the fish, but these are considered to be inseparable from the process of frozen storage. In addition, there are special considerations attached to the interaction of the freezing and *rigor mortis* processes. Fish frozen before the onset of *rigor mortis*, then thawed and cooked can sometimes have a peculiar metallic flavour and a mealy or "granulated coconut" texture, and as will be seen, provision for this kind of peculiarity is made in the final score sheet.

The pattern of deterioration of iced cod incorporated into the cooked odour and flavour part of the score sheet of Shewan *et al.* (1953) has been taken as a working initial basis for describing the changes occurring in frozen cod during the unfrozen stage of its history. The validity of applying this scoring system to frozen cod has been tested as described below, paying particular attention to the question whether the whole range of cooked odours and flavours present in iced cod is detectable in frozen and thawed cod of various pre-freezing freshness. The part of the scoring system of Shewan *et al.* (1953) which refers to texture was replaced by fuller descriptions taking into account the special textural features encountered in frozen stored cod.

As far as organoleptic characteristics are concerned, frozen white fish during storage can deteriorate in three ways, namely in odour, in flavour and in texture (Banks, 1962). Flavour deterioration takes the form of a gradual intensification as frozen storage proceeds of an unpleasant and characteristic flavour in the cooked product; associated with this flavour is an odour of similar characteristics. Texture deterioration takes the form of an increasing impression of firmness or toughness on eating the frozen stored and then cooked fish; associated with this developing firmness is an increased impression of dryness to the palate. Most investigations of the deteriorations occurring in frozen stored white fish have in the past concentrated heavily on textural changes, flavour changes receiving little or no attention. However, it appears that odour and flavour are likely to contribute as much, if not more, to the overall assessment of quality as texture. Special attention has therefore been given to cold storage odours and flavours in this study; in particular, an attempt has been made to define them in terms of commonly encountered odours and flavours. In addition, the possible effect of initial spoilage before freezing on the subsequent development of different kinds of intensities of odours and flavours in the frozen fish has been studied. The textural variations presented by cod of various initial freshnesses and degrees of frozen storage deterioration have been analysed and codified.

In all cases the aim has been to construct practical scales by which the fish could be numerically scored. Throughout, the approach has been similar to that adopted by Shewan *et al.* (1953), in that the material under investigation has been evaluated as objectively as possible within the limits set by human perceptions. However, it was thought useful and indeed advisable to include in the scoring system allowance for preference judgments to be made by the taster on a purely subjective basis. The idea here is to correlate the preference of the panel members with particular changes in the various attributes of the frozen fish. In this way it was hoped that some idea of the relative importance of each attribute in relation to overall acceptability could be obtained.

Although the scoring system was meant to cover quite generally deteriorations in both the unfrozen and frozen

states, in fact the unfrozen deteriorations studied in this paper have been confined to the period before frozen storage. The present work therefore reduces to a study of *post rigor* cod of different initial freshnesses, frozen quickly, held for various periods in the frozen state at different temperatures, and then thawed quickly and cooked immediately. This study covers most of the conditions likely to be encountered in present-day whole, gutted fish and shore-based fillet freezing operations.

Materials

Almost all the work described in this paper has been carried out on cod caught throughout the year in the North Sea but, in addition, cod from other grounds has been examined. In all cases the fish were gutted immediately after catching, well packed in melting ice, and then frozen in an air-blast at −40°C (−40°F) either as whole fish or as skin-on fillets. After freezing, the whole fish were well glazed, and the fillets closely wrapped in heavy-gauge aluminium foil to prevent desiccation. The fish were then immediately transferred to stores held at −14°, −22° and −29°C (+7°, −8° and −20°F).

Cooking methods

During the initial phases of this study it was felt necessary to establish conditions of thawing and cooking which would optimize the ability of the taste panel to detect organoleptic differences. The effect of waiting time between cooking and tasting was also taken into account. The criterion used in these assessments was a minimum loss in the frozen fish of "wet" fish characteristics. In addition, a preliminary collection of cooked odours and flavours was made.

Based on these results, which will be published elsewhere (Baines *et al.*), the final procedure adopted was as follows: the whole fish and fillets were thawed overnight at 5° and 2.5°C (41° and 36.5°F) respectively. Steaks weighing 7 oz (200 g) were cut from the whole fish and pieces weighing 4 to 6 oz (110 to 175 g) from the centre portion of the fillets. The samples were cooked in a closed casserole over boiling water for 30 min. Tasting was done immediately after cooking was completed, the fish being held at 60°C (140°F) whilst tasting proceeded.

Evaluation of appropriate descriptive terms for frozen cod, and construction of scales

The next phase of the study was the evaluation of the odours, flavours and textural characteristics occurring in frozen fish.

Persons trained in the use of the "wet" cod scoring system of Shewan *et al.* (1953), and experienced in tasting different kinds and qualities of fish were presented with cooked samples of cod of a wide range of icing and frozen storage histories. The processing history of the fish was unknown to the panel at the time of tasting, and the samples were presented in random order.

Odours and flavours. The tasters were asked to note the odour and flavour of the cod using as wide a vocabulary as they chose. It was agreed that there were present in the samples odours and flavours which differed from the usual "wet" spoilage odours and flavours and that these could be grouped into a few classes having a similar character. For odours these characteristic classes were as follows: acid, fragrant, musty and turnipy; and for flavours as follows: acid, bitter, sickly-sweet, turnipy, metallic, musty, singed. It was also agreed that the predominant odour and flavour which accumulates in frozen stored cod cannot be characterized by reference to a single odour or flavour or groups of commonly encountered odours or flavours. This predominant odour and flavour has been termed the "cold storage odour and flavour".

In further sessions, the panel was asked to mark the intensity of cold storage odour and flavour in each sample on a six-point scale in addition to noting the occurrence of the characteristic classes just described. There was a reasonable degree of agreement between the tasters as far as intensities of cold storage odour and flavour were concerned. The average frequencies of mention of the classes present in cod of various processing histories is shown in table 1. It is clear that, with the possible exception of "acid", no particular class is associated with any particular icing or frozen storage condition. From this result, and the discussions among the panel members, it is evident that, within the conditions of the experiment, the kinds of odours or flavours occurring in frozen stored cod are essentially independent of initial freshness or frozen storage history. The final score sheet, therefore, uses only a single descriptive term for cold storage odour and flavour which can be scored on an intensity scale and which is meant to be learnt by training.

Provision was made in the final score sheet for noting the occurrence of odours and flavours which were not covered by the other scales.

Texture. In a similar manner the panel concentrated on textural characteristics, using initially, the texture scales of Baines and Shewan (1965), together with written descriptions of any additional textural characteristics. The scale for fibrousness was not used in this phase both because preliminary work had indicated that fibrousness scores were very variable (Torry Research Station 1965) and because the descriptions used in the scale did not truly represent the kind of graduated change occurring in frozen fish.

Examination of the scores for firmness and dryness as well as comments from the panel members showed that these two characteristics could be used in a meaningful way and that no other scales were required to cover the textural variations encountered in frozen cod of the kind examined. However, it was decided that some descriptive terms in the original firmness and dryness scales of Baines and Shewan (1965) were either too ambiguous or detracted from the sense of gradation in the scale, and these were omitted. In addition, it was felt necessary to define more closely the meaning of "normal" firmness and dryness because these characteristics are subjected to a certain amount of intrinsic variation even in unprocessed material. For example, firmness of cod depends upon degree of spoilage, intrinsic variations in pH (Kelly *et al.*, 1966) and, possibly, season when caught. "Normal" is therefore taken to mean the average value of randomly selected samples of two to five days iced North Sea cod having all possible pH's and caught at all seasons of the year.

TABLE 1. FREQUENCY OF MENTION OF PARTICULAR FLAVOUR CLASSES IN COD OF VARIOUS INITIAL FRESHNESSES STORED AT −14°C FOR UP TO 35 WEEKS

Freshness (days in ice before freezing)	*Weeks at −14°C*	*Frequency of mention of a particular class*						
		Acid	*Bitter*	*Sickly-sweet*	*Turnipy*	*Metallic*	*Musty*	*Singed*
2	1	2	0	6	3	2	0	1
	5	2	0	7	6	1	1	0
	8	3	1	6	3	2	1	0
	13	3	1	5	5	1	3	0
	16	5	2	4	4	2	2	1
	23	4	1	5	4	1	4	1
	35	5	1	7	3	0	3	2
	Mean	3.4	1.0	5.7	4.0	1.3	2.0	0.7
5	1	1	0	1	3	0	1	0
	5	0	0	0	4	0	1	1
	13	1	0	1	5	1	1	0
	21	3	0	3	5	1	0	0
	25	4	0	2	4	3	1	1
	35	6	1	2	5	1	2	0
	Mean	2.5	0.2	1.5	4.3	1.0	1.0	0.3
8	1	2	2	4	5	1	0	1
	5	2	1	2	4	2	0	1
	7	2	1	4	3	2	2	1
	11	3	1	2	5	2	0	0
	15	3	1	2	5	0	2	1
	17	3	1	4	4	2	2	1
	23	4	1	4	4	1	0	1
	35	4	1	6	6	1	2	1
	Mean	2.9	1.1	3.5	4.5	1.4	1.0	0.9
14	2	3	0	1	6	1	1	0
	4	2	4	0	3	0	1	0
	7	3	3	2	4	2	2	2
	14	3	1	1	2	2	1	1
	16	5	3	3	5	2	1	1
	20	2	3	2	4	1	3	1
	24	5	1	2	5	1	1	1
	34	4	2	2	5	1	0	1
	Mean	3.4	2.1	1.6	4.3	1.3	1.3	0.9

Provision has been made in the firmness scale for degrees of firmness lower than "normal", by including numerical scores of 0 and 1; similarly on the dryness scale a score of 0 denotes fish "wetter" or sloppier than normal. The firmness and dryness scales are thus finally more in the nature of intensity scales than a list of descriptions of characteristics which change during the course of frozen storage. As with odour and flavour, provision has also been made for textural variations by including space on the score sheet for descriptions of additional characteristics together with a list of commonly used terms.

The freshness (unfrozen or iced fish) scale

After the above amount of experience with frozen cod, and participation in the construction of the score sheet for cold storage odour and flavour and for texture, the panel were asked over a number of sessions to score a wide variety of cod for freshness using, as mentioned in the introduction, the "wet" fish cooked odour and flavour scales of Shewan *et al.* (1953). These two scales are called for convenience freshness scales. It should be noted that some authors use the term "freshness" to describe the overall deterioration undergone by the frozen fish, including that occurring in the frozen state. In the work described here freshness refers to the initial quality of the fish before freezing and frozen storage.

The cod employed in this phase included a high proportion of samples having very strong cold storage odour and flavour and very tough texture. Despite this and the fact that the panel knew nothing of the processing history of the fish, examination of the scores indicated both that the freshness scales could be used effectively, and that the panel were capable to a useful degree of precision of distinguishing between samples which differed in freshness. This point is illustrated in table 2 which shows the

TABLE 2. MEAN PANEL FRESHNESS FLAVOUR SCORES OF COD OF DIFFERENT INITIAL FRESHNESSES STORED AT TEMPERATURES OF −14°, −22° AND −29°C FOR PERIODS UP TO ONE YEAR, COMPARED TO UNFROZEN COD TASTED AT THE SAME TIME

Days in ice	*Freshness flavour score*	
	Frozen	*Unfrozen*
1		8.20 (3)
2	7.40 (15)	
3		7.75 (2)
4		7.85 (4)
5	7.02 (22)	
7		7.70 (3)
8	6.92 (13)	7.40 (2)
12		6.80 (1)
13		5.00 (2)
14	4.81 (18)	4.50 (1)
17	3.50 (11)	3.80 (1)

The figures in brackets are the number of samples tasted.

average freshness scores of samples having various degrees of frozen storage deterioration together with corresponding scores of unfrozen fish tasted at the same time.

THE FINAL SCORE SHEET

The column headings on the finally agreed score sheet are as follows: sample no., freshness odour, cold store odour, odour description (if any additional), freshness flavour, cold storage flavour, flavour description (if any additional), firmness, dryness, texture description (if any additional), overall acceptability. The accompanying scales to be used with the sheet are shown in table 3. The freshness odour and freshness flavour scales are, as stated above, those of Shewan *et al.* (1953).

All the odour scores are grouped together for convenience, likewise the firmness and texture scores. As mentioned above, a score is also given for overall acceptability on the nine-point hedonic scale (Peryam and Girardot, 1952) shown in table 3.

THE SCORE SHEET IN USE

As the scoring system includes three intensity scales it is necessary to train the panel members to memorize particular levels of intensity, and to reach agreement on the level of intensity to be given any particular sample of fish. The intensity of cold storage odour and flavour and degree of firmness and dryness increase progressively as frozen storage proceeds, and the question therefore arises as to the amount of deterioration which should be aligned with the extreme scores of the intensity scales. For example, how long should cod be stored at −14°C (+7°F) before it can be termed very tough? It has been found empirically that there is very little, if any, increase in the firmness or cold storage odour and flavour of cod held at −14°C (+7°F) for longer than one year. Therefore, it was decided to align a score of very strong (on the odour and flavour scales) or extremely tough (on the firmness scale) with fish which had been stored at −14°C (+7°F) for one year. Fresh cod held under these conditions would be generally considered to be inedible, and so the alignment of the scale selected is believed to be a practicable one.

After the panel were familiar with the scoring system, the progress of their training was examined and the scoring system tested by again asking them over a number of sessions to taste cod of various initial freshnesses held at temperatures of −14°, −22° and −29°C (+7, −8° and −20°F) for periods of 0 to 50 weeks. An analysis of variance was then separately carried out on the results of each session. The error variances, representing the scoring variations, are shown for the consecutive sessions in table 4. Over this series of sessions

TABLE 3. SCORE SHEET FOR COOKED, FROZEN COD

Freshness odour and freshness flavour

Scored as for cooked, unfrozen cod

Cold store flavour and odour

0 Absent
1 Very slight
2 Slight
3 Moderate
4 Strong
5 Very strong

Firmness

0 Very soft
1 Softer than normal
2 Firm (normal two to five days iced unfrozen North Sea cod)
3 Slightly firmer than normal
4 Slightly tough
5 Tough
6 Extremely tough

Dryness

0 Sloppy, watery
1 Juicy, moist (normal, fresh, unfrozen North Sea cod)
2 Slightly dry
3 Dry
4 Extremely dry

Additional Texture descriptions

E.g. mushy, mealy, granulated coconut, fibrous, stringy, rubber bands, chewy, woody

Overall acceptability

9 Like extremely
8 Like very much
7 Like much
6 Like slightly
5 Neither like nor dislike
4 Dislike slightly
3 Dislike much
2 Dislike very much
1 Dislike extremely

the error variances of the panel scores do not change, indicating that the panel is not improving in precision and on these grounds can be considered trained. The magnitude of the error variances shows that the various scales are of reasonable length. For the freshness odour and flavour scores, the error variances are larger than usually encountered for unfrozen fish when a trained panel is using the scheme of Shewan *et al.* (1953). However, for firmness and dryness they are less than the values quoted for a partly trained panel using the texture scales of Baines and Shewan (1965).

By means of this scoring system it has been shown possible to distinguish and assess reasonably accurately the various attributes which go to make up the final quality of any sample of frozen cod. In this it is an advance on previously used systems which measure only either one or two attributes, or the overall grade regardless of attributes. The scheme is now in regular use at Torry Research Station, and has been used as described in an accompanying paper both to plot the course of deterioration in frozen cod of various initial freshnesses and to assess the usefulness of several objective tests of quality.

TABLE 4. ERROR VARIANCES OF SCORES OF A PANEL OF 12 MEMBERS TASTING, DURING FIVE SESSIONS, COD OF VARIOUS INITIAL FRESHNESSES HELD AT −14°, −22° AND −29°C FOR 0 TO 50 WEEKS

Session No.	*Freshness*		*Cold storage*			
	Odour	*Flavour*	*Odour*	*Flavour*	*Firmness*	*Dryness*
1	0.71	0.69	1.06	0.69	0.22	0.37
2	0.40	0.48	0.52	0.61	0.22	0.26
3	0.45	0.49	0.78	0.75	0.44	0.18
4	0.39	0.38	1.02	0.90	0.32	0.09
5	0.65	0.58	0.34	0.39	0.23	0.24

References

ANDERSSON, K and DANIELSON, C E *Fd Technol., Champaign,* 1961 **15,** 15.

ARMSTRONG, I L, PARK, E W, MCLAREN, B A and PARKER, 1960 D S *J. Fish. Res. Bd Can.*, **17,** 1.

BAINES, C R and SHEWAN, J M *Lab. Pract.*, **14,** 160. 1965

BANKS, A *Annex 1962–1 Bull. int. Inst. Refrig.*, p. 445. 1962

COWIE, W P and LITTLE, W T *J. Fd Technol.*, **1,** 335. 1966

DYER, F E and DYER, W J *J. Fish. Res. Bd Can.*, **7,** 449. 1949

EHRENBERG, A S C *Fd Technol., Champaign,* **7**(4), 188. 1953

GUTSCHMIDT, J *Proc. XI Int. Congr. Refrig.*, Munich, **2,** 923. 1965

HEERDT, M and STANSBY, M E *Comml Fish. Rev.* **17**(3), 13. 1955

KELLY, K, JONES, N R, LOVE, R M and OLLEY, J *J. Fd* 1966 *Technol.*, **1,** 9.

LILJEMARK, A *Fd Technol., Champaign,* **18**(3), 122. 1964

LOVE, R M *J. Fd Technol.*, **1,** 141. 1966

MOORJANI, M N, MONTGOMERY, W A and COOTE, G C 1960 *Fd Res.*, **25,** 263.

PERYAM, D R and GIRARDOT, N F *Fd Engng,* **24,** 58. 1952

PETERS, J A, COHEN, E H and KING, F J *Fd Technol.,* 1963 *Champaign,* **17**(6), 109.

SHEWAN, J M, MACINTOSH, RUTH G TUCKER, C G and 1953 EHRENBERG, A S C *J. Sci. Fd Agric.*, **4,** 283.

TORRY RESEARCH STATION *Annual Report,* Aberdeen, p. 12. 1965

Estimation of Hypoxanthine Concentrations in Fish Muscle by a Rapid, Visual Modification of the Enzymatic Assay Procedure

by J. R. Burt, G. D. Stroud and N. R. Jones

Estimation of hypoxanthine concentrations in fish muscle by a rapid, visual modification of the enzymatic assay procedure

The several existing methods of determining hypoxanthine concentrations in extracts of fish muscle differ in their accuracy, their ease and speed of execution and the amount of instrumentation required. The enzymatic assay procedure, which using xanthine oxidase monitors hypoxanthine as its oxidation product uric acid, requires complex instruments for its operation.

A method of simplifying this technique has been developed by incorporating the oxidation-reduction indicator, 2,6-dichlorophenolindophenol, into the reaction mixture. This is decolourized to an extent proportional to the amount of hypoxanthine present. Amounts of dye, whose total decolourization would correspond to a pre-set rejection limit and to levels just above and below that limit are used. Extracts of fish muscle can then rapidly be screened and classified as (a) well below, (b) just below, (c) just above, or (d) well above the rejection limit. A large number of extracts have been examined by this procedure and the fish from which they were prepared were classified with a high degree of accuracy. After comparing the results of this test with the correct hypoxanthine concentrations it was found that 94 and 95 per cent of the samples would have been correctly rejected and accepted respectively.

The advantages that the hypoxanthine test has over many other tests of fish freshness, particularly during the early *post-mortem* stages of autolytic deterioration makes it potentially of great use in screening iced fish prior to freezing ashore. In addition, hypoxanthine concentrations in stored frozen fish are known to be a good index of pre-freezing quality.

Evaluation des concentrations d'hypoxanthine dans le muscle du poisson au moyen d'une rapide modification visuelle du procédé d'essai enzymatique

Les nombreuses méthodes actuelles de détermination des concentrations d'hypoxanthine dans les échantillons de muscle de poisson diffèrent entre elles quant à leur précision, à leur facilité et à leur rapidité d'application ainsi qu'à la quantité d'appareils nécessaires. Le procédé d'essai enzymatique qui, utilisant la xanthine-oxydase, contrôle l'hypoxanthine dans son produit d'oxydation, l'acide urique, exige un appareillage complexe pour son application.

Une méthode ayant pour but de simplifier cette technique a été mise au point en incorporant l'indicateur d'oxydoréduction, le 2,6-dichlorophénolindophénol, dans le mélange de réaction. Celui-ci subit une décoloration proportionnelle à la quantité d'hypoxanthine présente. On utilise des quantités de colorant telles que leur décoloration totale correspond à une limite de refus préétablie ainsi qu'à des niveaux immédiatement au-dessus et au-dessous de cette limite. Les extraits de muscle de poisson peuvent être rapidement examinés et classés dans les groupes (a) très au-dessous, (b) immédiatement au-dessous, (c) immédiatement au-dessus et (d) très au-dessus de la limite de refus. Un grand nombre d'extraits ont été examinés avec cette méthode, les poissons dont ils avaient été prélevés ayant été très soigneusement classés. Après comparaison des résultats de cet essai avec les concentrations correctes d'hypoxanthine, on a trouvé que 94 et 95 pour cent des échantillons auraient été respectivement refusés et acceptés.

Les avantages que l'essai de l'hypoxanthine présente par rapport à de nombreux autres essais de la fraîcheur du poisson, notamment au cours des premiers stades *post mortem* de la détérioration autolytique, le rendront très précieux pour l'examen et la sélection du poisson mis en glace avant la congélation à terre. De plus il est connu que les concentrations d'hypoxanthine dans le poisson congelé entreposé constituent un bon indice de la qualité requise avant la congélation.

La estimación de las concentraciones de hipoxantina en el tejido muscular de los peces, mediante una modificación visual rápida del procedimiento de ensayo enzimático

Los distintos métodos existentes para determinar las concentraciones de hipoxantina en extractos de tejido muscular de los peces difieren en su precisión, su facilidad y rapidez de ejecución y en la cantidad de instrumentos que hacen falta. El procedimiento de ensayo enzimático, que empleando la xantin-oxidasa revela la hipoxantina en forma de su producto de oxidación (el ácido úrico), exige complejos instrumentos para su operación.

Se ha simplificado esta técnica incorporando en la mezcla reactiva el indicador de óxido-reducción 2,6 diclorofenolindofenol. Aquélla se decolora en medida proporcional a la cantidad de hipoxantina presente. Se emplean cantidades de colorante cuya decoloración total correspondería a un límite preestablecido de exclusión y a niveles por encima y por debajo de dicho límite. Entonces se pueden analizar y clasificar extractos de tejido muscular de peces (a) muy por debajo, (b) exactamente por debajo, (c) exactamente por encima, o (d) muy por encima del límite de exclusión. Con este procedimiento se ha examinado un gran número de extractos y el pescado a partir del que se preparó se clasificó con un alto grado de precisión. Después de comparar los resultados de esta prueba con las correctas concentraciones de hipoxantina se halló que el 94 y el 95 por ciento de las muestras, respectivamente, se habían rechazado y aceptado de un modo correcto.

Las ventajas que la prueba de la hipoxantina tiene sobre otras muchas pruebas de la frescura del pescado, especialmente durante las etapas iniciales *post-mortem* de descomposición autolítica, hacen que, potencialmente, tenga un gran empleo para seleccionar el pescado helado antes de congelarlo en tierra. Además, se sabe que las concentraciones de hipoxantina en el pescado congelado almacenado son un buen índice de su calidad antes de la congelación.

THE determination of the concentration of hypoxanthine in fish muscle and the use of such a value as an index of quality have been the subjects of several recent papers (Hughes and Jones, 1966; Jones, 1960; 1965; Jones and Murray, 1962; Jones *et al.*, 1964; Jones, Murray and Burt, 1965; Kassemsarn *et al.*, 1963; 1964). The enzymatic assay procedure, which depends on the measurement of the uric acid produced from hypoxanthine in the reaction catalysed by xanthine oxidase, has been shown to be the most convenient for reasons of simplicity, accuracy and rapidity. It suffers, however, from the requirement for expensive and sophisticated equipment and this is particularly true in the case of the automated, enzymatic assay procedure (Jones, Murray and Burt, 1965).

The modification of the enzymatic assay procedure described in this paper has involved the incorporation of a redox indicator-dye solution into the reaction mixture which contains a neutralized, acid extract of fish muscle, phosphate buffer and xanthine oxidase. The dye changes

colour to an extent proportional to the amount of hypoxanthine present in the reaction mixture. Dyes which lose their colour as the reaction proceeds were considered in principle to be the most suitable and the properties of several were investigated. Difficulties were encountered with some reverting to the coloured state almost as fast as they were decolourized. Methylene blue was particularly bad in this respect and was rejected in favour of 2,6-dichlorophenolindophenol. Additionally the dyes phenolindophenol, Laurer's violet, phenol blue and pheno safranine were tested with varying success but not found to be any better than the dichlorophenolindophenol.

It was envisaged that, by using a limiting concentration of dye which corresponds to a pre-determined rejection limit in terms of hypoxanthine concentration, extracts of fish muscle could be assessed rapidly and easily. This idea has been developed a little further and it has proved more convenient and reliable to use three concentrations of dye, one of which corresponds to such a rejection limit and the others to levels 20 per cent above and below that limit. Depending on which of the three mixtures is completely decolourized by a particular extract, the fish from which it was prepared can then be classified as well below, just below, just above or well above the rejection limit. Of the two possible ways of altering the position of this rejection limit it has been found better to vary the strength of the extract and to work always with the same strengths of dye. The levels that were finally decided on are 40, 50 and 60 μg of 2,6-dichlorophenolindophenol and these are just completely decolourized by 10, 12 and 15 μg of hypoxanthine respectively in a reaction mixture of 5 ml.

For the purpose of testing the method the extraction procedure was tailored so that fish muscle with a hypoxanthine concentration of 1.91 μmole/g would give an extract containing 12 μg/ml. To reach this level, North Sea cod (*Gadus callarias*) would have to be, on average, in ice for about 13 to 14 days (Jones *et al.*, 1964). Extracts with 10 and 15 μg hypoxanthine/ml would be obtained similarly from North Sea cod after 12 and 14 to 15 days in ice respectively. In addition, a few of the extracts investigated were prepared from fresher cod (about six days in ice), in which cases double the size of muscle sample was taken, and from haddock (*Gadus aeglefinus*). As the hypoxanthine content of fish muscle is known to vary along the length of a fish, samples were removed in each case from a point about 1 in behind the head.

Attempts were made at this stage to simplify the various stages of the extraction procedure which involves, successively:

(1) Weighing a piece of muscle.
(2) Homogenizing it with a known volume of perchloric acid solution.
(3) Filtering the homogenate.
(4) Neutralizing measured portion of the filtrate.
(5) Adjusting to a final volume.

It is not possible to obviate the requirement for a balance in step (1) by punching out cylinders of flesh with a cork borer, but the measurements of the volumes of liquids in steps (2), (4) and (5) can be put on a semi-automatic basis by the use of syringes and volumetric liquid dispensers. The need for a pH meter in step (4) has been overcome by incorporating buffer with the neutralizing alkali but it has not proved possible to replace the homogenizer with scissors nor the acid with hot water.

METHOD

Reagents required

Perchloric acid; 0.6 N.

Buffered KOH solution; prepared by mixing potassium hydroxide (20 per cent w/v in water) with a phosphate buffer solution (0.4 M; pH 7.6) in the ratio 42 : 58 (v/v).

Buffered dye solutions; phosphate buffer (0.17 M; pH 7.6) containing 40, 50 or 60 μg 2,6-dichlorophenolindophenol per 3 ml. These are stable at 0° to 4°C (32° to 39°F) for at least two months.

Xanthine oxidase solution; 0.040 International Units/ml, prepared by dilution of a commercial preparation of the enzyme with chilled, distilled water. Fresh dilutions need to be prepared daily and kept chilled until used.

Standard hypoxanthine solutions; a range of hypoxanthine solutions containing 9 to 16 μg hypoxanthine/ml (in 1 μg/ml increments), prepared by dilution from a more concentrated solution. The dilute solutions are stable at 0° to 4°C (32° to 39°F) for two weeks.

Extraction of fish muscle

Remove a 5-g portion of muscle from the anterio-dorsal region of the fish and homogenize it with 50 ml 0.6 N perchloric acid. To 25 ml of the filtered homogenate add 10 ml buffered KOH and water to make a total volume of 50 ml. Of this extract, 21.6 ml is equivalent to 1 g of muscle.

Estimation of hypoxanthine

An aliquot portion (1 ml) of the extract is added to 3 ml of each of the buffered dye solutions in separate tubes. The reaction is started by the addition of 1 ml portions of the enzyme solution and the tubes observed for decolourization. The level of concentration of hypoxanthine present in the extract, and hence in the muscle, can be estimated according to which strength(s) of dye is completely decolourized. For calibration purposes, standard solutions of hypoxanthine are processed periodically.

The majority of tests were carried out at room temperature and complete reaction usually occurred within 5 min using the enzyme concentration specified. Reaction times of 2 min are required if half the amount of enzyme is used and incubation temperatures increased to 35° to 40°C (95° to 104°F). This would lead to a substantial saving in the cost of each test.

RESULTS AND DISCUSSION

Using the procedure described above, 266 extracts prepared from fish of different icing histories were examined and placed into one of the four possible categories. They were also analysed accurately for their true hypoxanthine content by one of the enzymatic assay procedures (Jones *et al.*, 1964; Jones, Murray and Burt, 1965) and the two sets of results were compared. Table 1 shows the results of these comparisons in terms of the numbers of extracts that were correctly assigned to each

TABLE 1. COMPARISON OF ASSESSMENTS WITH TRUE HYPOXANTHINE VALUES

	Category	Score					Percentage correct	
Numbers of extracts assigned by the dye procedure to the various categories in relation to the rejection limit	Well above	4	0	0	2	42	95	94
	Just above	3	0	5	20	13	53	
	Rejection limit	→						
	Just below	2	5	42	6	1	78	95
	Well below	1	107	20	1	2	82	
		Score	1	2	3	4		
		Category	Well below	Just below	Just above	Well above		
			Rejection limit					
			Numbers of extracts found to have true hypoxanthine contents lying within the concentration ranges corresponding to the various categories of the dye procedure					

category, those that were placed too high and those too low. For example, of the 54 extracts assessed by the dye procedure to be just below the rejection limit, five should have been placed in the category below, six in the one just above and one in that still higher. It will be noticed that the wrong predictions were seldom more than one category out. Also included in the table are the percentage-correct predictions that were made in each category and the percentage of the extracts that would have been correctly accepted or rejected on the basis of this test.

The categories were given scores of 1 to 4 in ascending order of hypoxanthine concentration and a statistical analysis made of these results. The equation that relates the score obtained by this dye procedure (V) to the true score (T) is

$$T = 0.932V + 0.275,$$

with a standard error of 0.516 around this prediction line. As a scoring system of discrete whole numbers was employed a simple application of the usual deductive statistical procedures cannot be made for determining the probability of a single assessment being correct. However, the average score of a batch of samples tested by this procedure can be related to the true value, which would have been obtained by accurately determining the average hypoxanthine concentration, by this equation in which the standard error of the predicted value of T will be $0.516/\sqrt{N}$ (where N is the number of samples in the batch). Hence the probability of the found average value being the same as any given one can be calculated by the application of normal statistical methods.

Early work indicated (*Anon.*, 1959) that the determination of hypoxanthine concentrations in fish muscle might form the basis of a useful index of quality particularly during the initial stage of chill-storage where many other quality tests, which monitor bacterial spoilage, are insensitive. Several fish species (table 2) have been investigated in this respect and, with the exception of the genus *Oncorhynchus*, have proved themselves more or less suitable subjects for the hypoxanthine test. It is possible that the test may be even more widely applicable since indications

TABLE 2. FISH IN THE MUSCLE OF WHICH HYPOXANTHINE CONCENTRATIONS HAVE BEEN DETERMINED DURING PERIODS OF CHILL-STORAGE

Common name	*Scientific name*	*Reference*
Coalfish	*Gadus virens*	Jones (1963) Jones *et al.* (1964)
Cod, Faroes	*Gadus callarias*	Jones *et al.* (1964)
Iceland	,, ,,	Jones *et al.* (1964)
North Sea	,, ,,	Jones (1963) Jones and Murray (1962) Jones *et al.* (1964)
Haddock	*Gadus aeglefinus*	Jones (1963) Jones *et al.* (1964) Kassemsarn *et al.* (1963)
Halibut	*Hippoglossus*	Spinelli (1967)
Herring	*Clupea harengus*	Hughes and Jones (1966)
Ocean perch	*Sebastes alutus*	Spinelli, Eklund and Miyauchi (1964)
Plaice	*Palalichtys olivaceous*	Uchiyama *et al.* (1966)
	Pleuronectes platessa	Jones (1963) Kassemsarn *et al.* (1963)
Salmon, Atlantic	*Salmo salar*	Murray, Jones and Burt (1966)
Chum	*Oncorhynchus keta*	Creelman and Tomlinson (1960)
Coho	,, *kisutch*	,, ,,
Pink	,, *gorbuscha*	,, ,,
Spring	,, *tshawytscha*	,, ,,
Sole, English	*Parophrys vetulus*	Spinelli, Eklund and Miyauchi (1964)
Lemon	*Pleuronectes microcephalus*	Jones (1963) Jones *et al.* (1964) Kassemsarn *et al.* (1963)
Petrale	*Eopsetta jordani*	Spinelli, Eklund and Miyauchi (1964)
South-west Atlantic fish	Three species	Valencia, Casávola and Sanahiha (1966)
Swordfish	Xiphias gladius	Dyer, Fraser and Lohnes (1966)
Whiting	*Gadus merlangus*	Jones *et al.* (1964)

have been obtained with other species of fish that hypoxanthine concentrations increase during chill-storage although it is a combined inosine plus hypoxanthine fraction that has been studied in these cases (Saito, Arai and Matsuyoshi, 1959; Ehira and Anekawa, 1966).

Jones (1963), using a uniform batch of cod frozen together immediately after capture, found that the concentrations of hypoxanthine in their muscle increased slightly during storage at −14°C (+7°F) but not at lower temperatures. More recent work by Connell (1967), in which cod of varying degrees of freshness were frozen at different times throughout a period of 14 months and were then thawed out together, failed to demonstrate such a rise during frozen storage at −14°C. The data suggested that there was an increase with time of storage at −14°C but this was not statistically significant at the 95 per cent confidence level. A similar, unpublished experiment with haddock did show that statistically highly significant increases in hypoxanthine concentration were found to occur during frozen storage with fish that had been in ice for less than eight days before freezing, but not with staler fish. However, Connell (1967) showed that measurements of the hypoxanthine concentration of frozen cod muscle correlate very well with the length of storage in ice prior to freezing and can also be used (in the case of staler fish) to predict its freshness flavour. The reason for the disparity between these two sets of results obtained from cod in respect of changes in hypoxanthine concentration during storage at −14°C has been ascribed by Connell to the differing biochemical states of the material used. The variations inherent in a mixed batch of fish, such as was used by him, would have swamped any rise had it occurred. However, the results did show that, for each group of cod with equivalent initial freshnesses, the mean hypoxanthine concentration at −14°C differed from that at −22°C and from that at −29°C. This difference can be explained by the known pattern of rise and fall in hypoxanthine concentration in iced fish (Jones, 1963) and by a slight continuation of the concentration change, in the direction it was going before freezing, during storage at −14°C. Saito, Arai and Matsuyoshi (1959) also applied their objective index (a measure of the amount of inosine plus hypoxanthine present) to frozen fish and demonstrated a relationship between it and a sensory evaluation of the raw fish before freezing.

The versatility and simplicity of this modified hypoxanthine test make it potentially useful in a variety of circumstances. The rejection limit can be preset at any point in the range of possible hypoxanthine values by manipulating the extraction procedure and as many warning limits as are desired can be placed at any position above and/or below that rejection limit by judicious selection of dye concentrations. Within the terms of reference of this Conference there are at least two major applications for this test: it can be used to screen wet fish for its suitability as the raw material for a frozen product and to assess certain aspects of the quality of frozen fish.

Acknowledgments

Mr. P. F. Howgate carried out the statistical analysis. This work was carried out as part of the programme of the Torry Research Station.

References

ANON. *Torry Research Station Annual Report*, Department of Scientific and Industrial Research, HMSO, London, p. 26. 1959

CONNELL, J J FAO Technical Conference on the Freezing and Irradiation of Fish, 4th–8th September, Madrid. 1967

CREELMAN, V M and TOMLINSON, N *J. Fish. Res. Bd Can.*, **17**, 449. 1960

DYER, W J, FRASER, D I and LOHNES, D P *Ibid.*, **23**, 1821. 1966

EHIRA, S and ANEKAWA, M *Bull. Jap. Soc. scient. Fish.*, **32**, 716. 1966

HUGHES, R B and JONES, N R *J. Sci. Fd Agric.*, **17**, 434. 1966

JONES, N R *Analyst, Lond.*, **85**, 111. 1960

JONES, N R *Proc. XI Int. Congr. Refrig.*, Munich, p. 917. 1963

JONES, N R In *Technology of Fish Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 179. 1965

JONES, N R and MURRAY, J *J. Sci. Fd Agric.*, **13**, 475. 1962

JONES, N R, MURRAY, J and BURT, J R *J. Fd Sci.*, **30**, 791. 1965

JONES, N R, MURRAY, J and (in part) LIVINGSTON, E I and MURRAY, C K *J. Sci. Fd Agric.*, **15**, 763. 1964

KASSEMSARN, B.-O., SANZ PEREZ, B, MURRAY, J and JONES, N R *J. Fd Sci.*, **28**, 28. 1963

MURRAY, J, JONES, N R and BURT, J R *J. Fish. Res. Bd Can.*, **23**, 1795. 1966

SAITO, T, ARAI, K and MATSUYOSHI, M *Bull. Jap. Soc. scient. Fish.*, **24**, 751. 1959

SPINELLI, J *J. Fd Sci.*, **32**, 38. 1967

SPINELLI, J, EKLUND, M and MIYAUCHI, D *Ibid.*, **29**, 710. 1964

UCHIYAMA, H, SUZUKI, T, EHIRA, S and KANNA, K *Proc. II Int. Congr. Fd Sci. Technol.*, Warsaw, Abstract B.3.3. 1966

VALENCIA, M, CASÁVOLA, H and SANAHUJA, J C *Proc. VII Congr. Panamericano de Farmacia y Bioquimica*, Buenos Aires. 1966

Objective Measurement of the Hardness Parameter in Cooked Fish Muscle

by A. H. Sutton and G. Main

Objective measurement of the hardness parameter in cooked fish muscle

There are two principal physical parameters which characterize cooked fish texture. These are hardness and succulence. Chewiness is also of importance, but since chewiness and hardness are generally closely associated, a separate measurement of this is rarely required. A combination of hardness, succulence and chewiness produce a major proportion of the possible cooked fish textures.

The hardness of muscle has a simple physical significance, and the problems associated with its objective measurement are purely instrumental. A penetrometer-type instrument was constructed which measures the pressure build-up when the sample is compressed to a fixed distance. In designing the equipment portability was considered to be an important factor, and our total instrument weight is less than 20 lb.

A good correlation has been found between the instrument and taste panel assessment of hardness. Statistical analysis of the results show that the instrument produces a more precise mean value of hardness than the taste panels, and it is hoped to improve this further. The main problem has been in obtaining uniform packing of the sample, this causing fairly large standard mean deviations in the results. This is overcome at present by taking a large number of samples, but various other preparative procedures are being investigated.

The instrument is proving to be a very useful tool where more precise texture measurements are required, and will be invaluable where trained taste panels are not available.

Mesure objective des paramètres de dureté dans la chair de poisson cuite

La texture du poisson cuit est caractérisée par deux paramètres physiques principaux, à savoir la dureté et la succulence. La masticabilité est également un facteur important, mais du moment qu'elle est en général étroitement associée à la dureté, la mesure séparée de ces deux facteurs est rarement nécessaire. C'est à la combinaison des trois facteurs en question—dureté, succulence et masticabilité—qu'est due principalement la texture finale du poisson cuit.

La dureté du muscle n'a qu'une signification physique et les problèmes posés par sa mesure objective sont de nature purement instrumentale. On a construit un instrument du type pénétromètre qui mesure l'augmentation de la pression provoquée par la compression de l'échantillon jusqu'à une distance donnée. La facilité de transport a été considérée comme un facteur important lorsque l'appareil a été projeté et son poids total est inférieur à 20 livres (9 kg).

On a constaté une assez bonne concordance entre les évaluations de dureté effectuées séparément par l'instrument et par un jury de dégustation. L'analyse statistique des résultats indique que l'instrument donne une valeur moyenne de la dureté plus précise que celle fournie par les jurys de dégustation et on espère améliorer ultérieurement cette précision.

Le problème principal consistait à obtenir un emballage uniforme des échantillons, ce qui a donné lieu à d'assez grandes différences moyennes dans les résultats. On remédie actuellement à cet inconvénient en utilisant un grand nombre d'échantillons; cependant, d'autres méthodes de préparation sont actuellement à l'étude.

L'instrument s'est avéré très utile lorsqu'il a été nécessaire d'effectuer des mesures plus précises de la texture et sera particulièrement précieux toutes les fois qu'on ne pourra pas disposer de jurys de dégustation qualifiés.

Medición objetiva del parámetro de consistencia de la carne del pescado cocinado

Los principales parámetros físicos que caracterizan la textura del pescado cocinado son dos: la consistencia y la jugosidad. La masticabilidad tiene también importancia pero puesto que ésta y la consistencia por lo general se hallan estrechamente relacionadas, raramente hace falta una medición separada de ella. Una combinación de consistencia, jugosidad y masticabilidad, constituye una importante proporción de las posibles texturas del pescado cocinado.

La consistencia de la carne tiene una significación sencillamente física, y los problemas relacionados con su medición objetiva son puramente instrumentales. Se construyó un instrumento del tipo del penetrómetro, que mide la presión ejercida cuando la muestra se comprime hasta un punto fijo. Al diseñar el equipo se consideró que la transportabilidad constituía un factor importante, y por ello el peso total del instrumento es inferior a los 10 kilogramos.

Se ha observado una buena correlación entre los resultados de la evaluación de la consistencia con el instrumento y los del equipo de catadores. El análisis estadístico de los resultados indica que el instrumento da un valor medio de la consistencia más preciso que los equipos de catadores, esperándose poderlo mejorar más adelante. El principal problema ha consistido en obtener un envasado uniforme de la muestra, lo que ha causado en los resultados desviaciones típicas medias bastante grandes. Actualmente esto se supera tomando gran número de muestras pero se están investigando otros varios procedimientos preparatorios.

El instrumento está demostrando ser muy útil cuando se necesitan mediciones de la textura más precisas, y será inapreciable cuando no se disponga de equipos de catadores.

A PRECISE and objective measurement of cooked fish texture is frequently required when assessing the effect of various processing methods, additives, storage conditions, etc., on the quality of the final product. Taste panel systems have the disadvantages of being expensive to run, difficult to train, and generally not very reliable, particularly over long periods of time. However, there are many formidable obstacles to the complete replacement of taste panels by instrumental methods, and it is likely that objective measurements will only supplement normal assessment procedures for some time to come.

The texture of cooked fish muscle can be largely defined in terms of two parameters, hardness and succulence. The hardness of muscle has a simple physical significance, and the problems associated with its measurement are purely instrumental. Succulence is a much more complex problem, since it is not related to the total water content, and its relation to the amount of "free" water is ill defined.

Muscle texture can either be measured directly by studying the rheological properties, or indirectly by observing some physical or chemical parameter related to texture. The latter techniques include cell fragility tests (Love and MacKay, 1962), changes in protein solubility (Dyer, 1950) and water binding capacity (Grau and Hamm, 1957). It is probable, however, that a study of the rheological properties will yield parameters more closely related to the sensory evaluations. The most widely used techniques are based on the compressive or

penetrative, shear and creep properties of the muscle (Szczesniak, 1963; Friedman, Whitney and Szczesniak, 1963; Shama and Sherman, 1967).

We have constructed a simple penetrometer-type instrument which measures the pressure required to compress the sample to a fixed distance. This is a measure of hardness and a good correlation between the instrument and taste panel has been found. Component weights and sizes were kept to a minimum, the total instrument weight being less than 9 kg providing a very portable piece of equipment.

DESCRIPTION OF THE INSTRUMENT

The basis of the method is to measure the force required to deform the sample through a fixed distance. The force is measured by strain gauges as the beam carrying the probe deflects. A strain gauge is a strip of material which changes its resistance when it is put under strain. The resistance is linearly related to the strain up to fairly large deflections, and is readily measured in a Wheatstone bridge circuit. The output of the bridge is fed to a chart recorder, or where only hardness is required a digital voltmeter could be used.

A photograph of the instrument is shown in fig 1. The framework and gear system were constructed from model engineering materials (Meccano). The measuring beam was formed by cementing two strain gauges (Philips PR9861) on either side of a strip of stainless steel size $1.0 \times 14 \times 0.1$ cm. This provides a very sensitive beam, which could be used for measuring the hardness of very soft materials. However, for cooked fish muscle this is desensitized by bolting together a suitable number of similar sized strips with spacing washers between each strip. The probe screws on to a bolt fixed through the centre of the beam, and is held in position with a locking nut. A small hook is soldered to the top side of the bolt, and this fastens a nylon thread running to a pulley directly over the beam and then through another fixed at the back of the box. This system is used for calibrating the strain gauges by attaching weights to the thread and recording the output.

The sample is driven on to the probe by a simple gear arrangement. The limits of travel are fixed by the micro-switches, which through a relay reverse the motor (fig 2). A Crouzet type 802 with a 60 rev/min gear box was used,

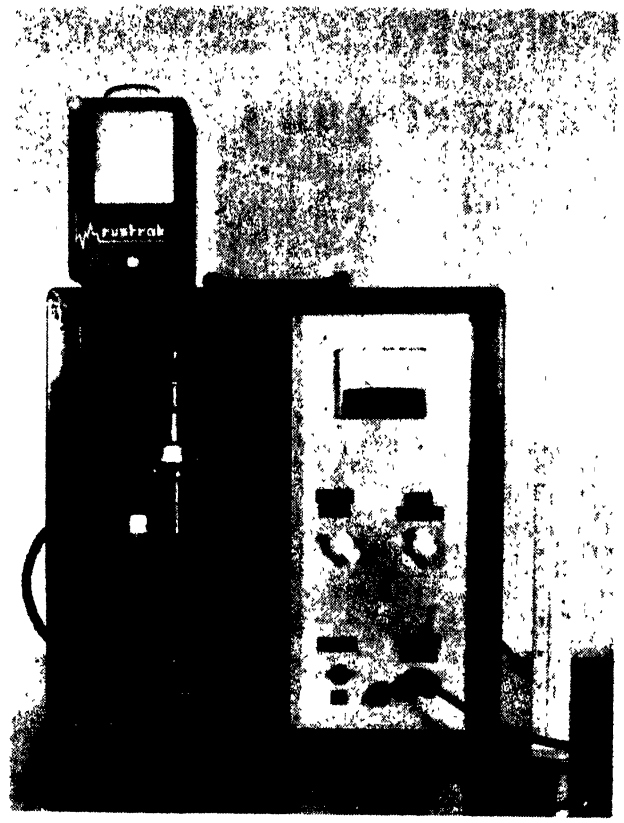


Fig 1. The texturometer

which gives approximately 1 cycle/min speed to the sample. Higher speeds could be used to advantage, but it is limited by the chart speed of the recorder.

The internal measurements of the sample cup are 1.9 cm diameter by 1.27 cm deep. The base of the cup is cut slightly larger than the rim, forming a lip. The cup slides into three locating pins on the platform, the heads of the pins overlapping the lip on the cup. This prevents the cup from lifting on the return stroke.

A diagram of the electrical measuring circuit is shown in fig 3.

A suitable recorder for this equipment should require 10 mV (1 mA) or less for full-scale deflection, fast pen response time and, if the curves are to be analysed in any

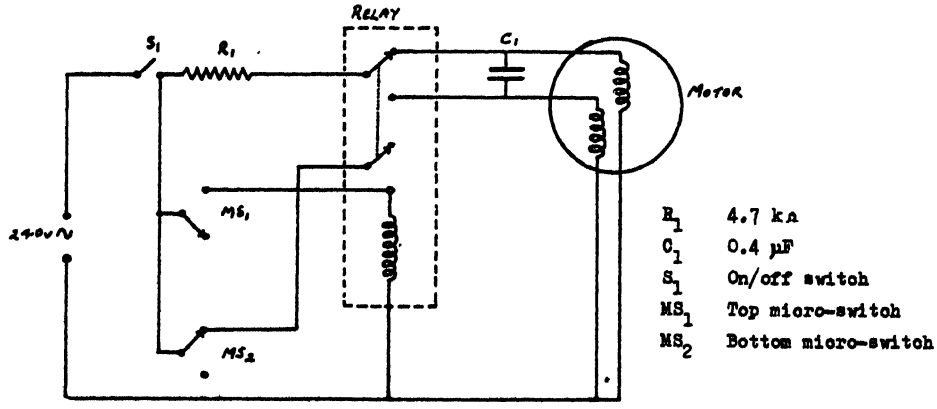
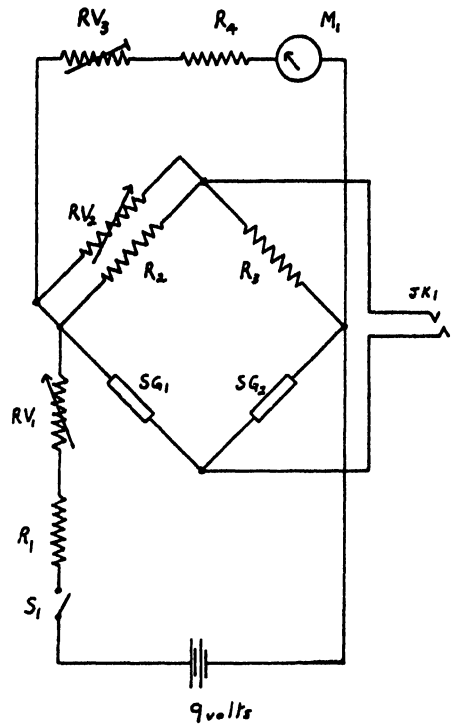


Fig 2. Circuit diagram for the control of the motor



R_1	50 Ω
R_2 and R_3	120 Ω
R_4	80 kΩ
RV_1	250 Ω
RV_2	5 kΩ
RV_3	30 kΩ
S_1	On/off switch
M_1	Meter 100 μA F.S.D.
SG_1 and SG_2	Strain gauges (Philips type PR 9861)
JK_1	Output

Fig 3. Diagram of measuring circuit

detail, fairly fast chart speeds (15 cm/min). For compactness, but with a slight loss of precision, we are using a Rustrak Model 88 miniature recorder.

Setting-up procedure

The micro-switches are adjusted to give a total movement greater than the cup depth, i.e. about 1.6 cm. The minimum gap between the probe and the bottom of the cup is then set by inserting the appropriate feeler gauge between the cup and the platform. With the cup at the top of its stroke, the probe is screwed down until a small deflection appears on the recorder. The probe is locked on this position, and the feeler gauges removed. The input voltage to the bridge circuit is adjusted to give a suitable matching output for the recorder.

The apparatus, once set up, should not require any further adjustment, other than for long-term wear of parts. The response of the beam can be checked periodically by weights, as when calibrating, and the rest of the system by measuring the hardness of a non-destructible substance, such as sponge rubber.

Preparation of samples

Both fresh and frozen cod were used in these experiments. For quality assessment the fillets were cooked by steaming in dishes over a water bath, 30 min for fresh fish and 60 min for frozen.

The most troublesome part of the investigation was finding a suitable sample preparative technique. It quickly became apparent that measurements on an intact portion of the muscle were not possible, because of the ease with which the samples disintegrated when manipulating them. Effort was therefore directed towards minced and macerated samples, and it was found that mincing the muscle and packing it to a constant volume gave fairly reproducible results and was a very simple technique. Work is continuing to find a more suitable mechanical system for packing samples. To correlate with this procedure the taste panel were asked to score hardness on the well-chewed muscle and not the initial impression.

A nine-point scale was used by the panel, from 0 to 4 in 0.5 units. 2.0 represents a perfect fish, with <2 soft and >2 tough.

INSTRUMENT–TASTE PANEL CORRELATIONS

The initial experiments with the instrument were carried out using a 0.318 cm diameter probe and a 0.152 cm gap. Samples being taste-panelled for a variety of other experiments carried out in the laboratory were also measured for hardness on the texturometer. No distinction was made between frozen and fresh fish. One sample per fish was taken and three readings in different parts of the cup obtained. The mean of these three readings are plotted against the taste panel score in fig 4. With some of the fish further samples and readings were obtained and the average percentage standard deviations were found to be 17 per cent.

There is quite a good correlation between the results, although the high standard deviations indicate that a lot of the scatter is due to instrument errors when only three readings are taken.

To investigate the mechanical variables which might affect the reproducibility of the results, we had at our disposal a considerably larger, but very versatile instrument based on the General Food Corporation Texturometer (Friedman, Whitney and Szczesniak, 1963). This instrument works on exactly the same principle as ours, but offered a wide range of probe and cup sizes and cycle speeds. Together with gap width these were considered the four instrument variables most likely to affect the

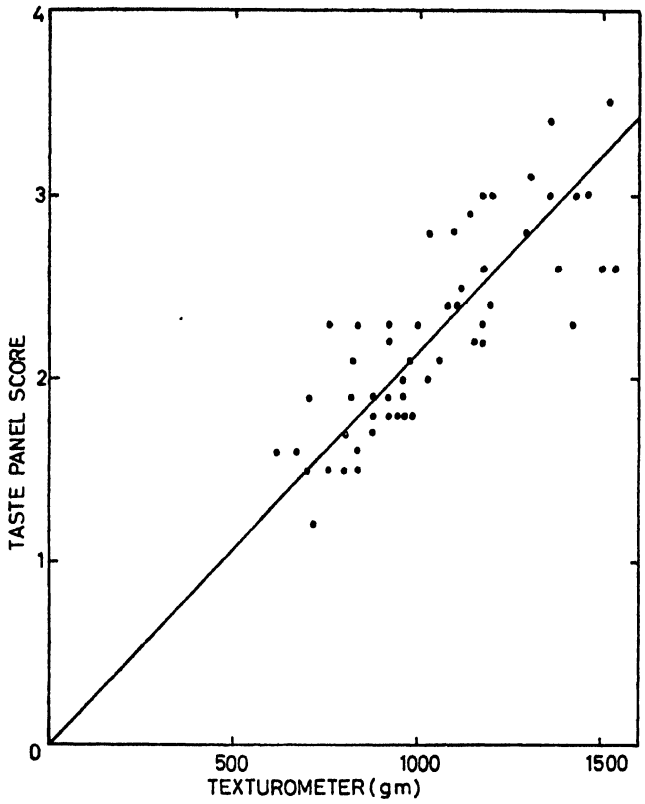


Fig 4. Relationship between texturometer (0.318 cm head) and taste panel

reproducibility. Different combinations of the following probe and cup sizes, gaps and speeds were investigated:

Probes: diameter: 0.635, 1.18, 2.54 cm
Cups: diameter: 1.91, 3.18, 4.44, 8.25 cm—all 2.22 cm deep
Gaps: 0.064, 0.127, 0.318, 0.610 cm
Speeds: 5½, 10, 20, 42 "bites"/min

For each set of parameters a large piece of fish was cooked and minced, providing a homogeneous sample. At least 10 results were obtained and the standard deviations calculated and expressed as a percentage of the mean values. These results are shown in fig 5.

Apart from the considerable improvement in increasing the probe size, the other variables did not seem to affect the reproducibility to any great extent.

Because of the low power of the motor and the type of construction materials used in our instrument the maximum size of probe was limited. For the instrument to have a reasonable life the probe size was restricted to 0.80 cm with a 0.394 cm gap.

With the larger head a separate cupful was required for each reading, and nine readings per fish were taken. The results are shown in fig. 6. The scatter of points does not seem to be greatly improved, although the average

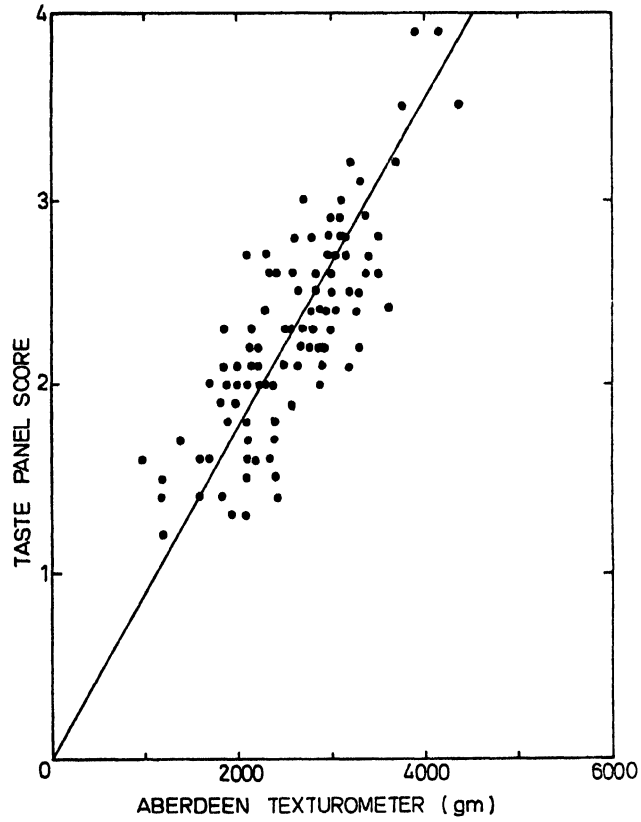


Fig 6. Relationship between Aberdeen texturometer (0.80 cm head) and taste panel.

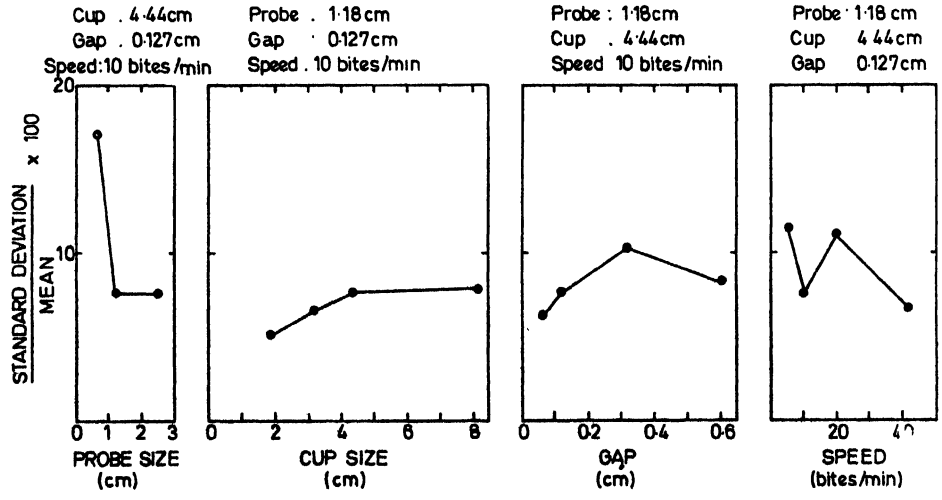


Fig 5. Effect of instrument variables on percentage standard deviation of results

percentage standard deviation is now 11 per cent. For this number of readings the measured hardness is within ± 7 per cent of the true value. However, when an analysis of variance was carried out on these results and compared with a similar analysis carried out on the taste panel for the same fish, it was shown that the ratio of the standard deviation between fish to that within fish was 4.1 : 1 for the texturometer and 2.7 : 1 for the taste panel. This means that the texturometer can distinguish between hardness with greater precision and sensitivity than the taste panel. (A ratio of 1 : 1 indicates the experimental error in the measurements is as large as the differences in hardness between the fish.)

CONCLUSIONS

An instrument for the objective measurement of the hardness parameter in cooked fish muscle has been successfully developed. Statistical analysis of results shows that the instrument is more sensitive to texture changes than a taste panel, and for the same number of observations gives a more accurate result. It has the advantage that further measurements are easily made where very precise results are required, and long-term stability makes results collected over a period of time strictly comparable. Being a portable instrument it is very useful where experiments are carried out in the absence of a trained panel, i.e. factory trials, etc. It could also be used as a quality control instrument where hardness is an important factor.

References

DYER, W J *J. Fish. Res. Bd Can.*, **7**, 585. 1950

FRIEDMAN, H, WHITNEY, J and SZCZESNIAK, A *J. Fd Sci.*, **28**, 1963 390.

GRAU, R and HAMM, R *Z. Lebensmittelunters. u. -Forsch.*, 1957 **105**, 446.

LOVE, R M and MACKAY, E M *J. Sci. Fd Agric.*, **13**, 200. 1962

SHAMA, F and SHERMAN, P Symposium on Rheology and 1967 Texture of Foodstuffs, London, January. (MS.)

SZCZESNIAK, A *J. Fd Sci.*, **28**, 410. 1963

Use of Ultra-violet Light for Determining whether Fresh or Frozen Fish Has Passed Through *Rigor Mortis*

by H. Wittfogel

Use of ultra-violet light for determining whether fresh or frozen fish has passed through *rigor mortis*

Ultra-violet light of 366 mμ wave-length causes a blue-white fluorescence from lactic acid present in very fresh fish and fish frozen before or during *rigor mortis*. This phenomenon provides a method of differentiating between fish frozen at sea, double-frozen fish and fish frozen on shore in the assessment of quality and in the daily fish inspection. This test for lactic acid in fish tissue has not been described before. The method is of value for scientific and commercial purposes.

Emploi des rayons ultraviolets pour déterminer s'il y a eu *rigor mortis* chez le poisson frais ou congelé

Les rayons ultraviolets d'une longueur d'onde de 366 mμ provoquent une fluorescence bleuâtre due à l'acide lactique se trouvant dans le poisson très frais ou dans le poisson congelé avant ou pendant la *rigor mortis*. Ce phénomène fournit un moyen de distinguer, lors de l'appréciation de la qualité et durant les inspections journalières des produits de la pêche, entre poisson congelé en mer, poisson soumis à congélation double, et poisson congelé à terre. Cette méthode de détection de l'acide lactique dans les tissus du poisson n'a jusqu'ici fait l'objet d'aucune description. Elle présente un grand intérêt tant scientifique que commercial.

El empleo de los rayos ultravioleta para determinar si el pescado fresco o congelado ha pasado a través del *rigor mortis*

Los rayos ultravioleta de 366 mμ de longitud de onda ocasionan una fluorescencia azul-blanca debida al ácido láctico que hay en el pescado muy fresco y en el pescado congelado antes o durante el *rigor mortis*. Este fenómeno proporciona un método de diferenciación entre el pescado congelado en el mar, el pescado recongelado y el pescado congelado en tierra, en la determinación de la calidad y en la inspección diaria del pescado. Esta prueba del ácido láctico en el tejido del pescado no se había descrito anteriormente. El método es útil con fines científicos y comerciales.

A METHOD of determining, quickly and precisely, whether fish has been frozen before or after the relaxation of *rigor mortis*, or whether fish has been thawed and refrozen, would frequently be useful for assessing quality and for other fish inspection purposes. Up to now there has been no practical test for this purpose.

Fish frozen at sea are usually frozen either during onset, duration or relaxation of *rigor mortis*. These three stages of *rigor mortis* are biochemically characterized by the presence of lactic acid in the fish tissue. Lactic acid can also be found in fish while they are still alive and for a short time after the relaxation of *rigor mortis*. The amount of lactic acid in the flesh depends on the condition of the animal nutritionally, how it is treated just prior to death and how far the decomposition of lactic acid has proceeded after death. High temperatures accelerate the depletion of lactic acid from the tissue.

The biochemical reduction of lactic acid in living fish and during the different stages of *rigor mortis* can be delayed by freezing and holding in cold storage. Rapid freezing and suitable cold storage at adequately low temperatures, low relative humidity and favourable environmental conditions keep lactic acid unchanged in the tissue for months. Thawing after freezing allows further decomposition of lactic acid and its eventual disappearance. Refreezing on the other hand arrests the further depletion of lactic acid in the fish tissue.

Fluorescence under ultra-violet light has been found to be a new practical method for the detection of lactic acid in the tissue of fish. This method can be used to distinguish between fish frozen at sea and fish frozen on shore as well as to indicate that double freezing has taken place. The test should be of value for both scientific and commercial purposes.

METHOD

Principle

The method relies on the property of lactic acid to emit a blue-white fluorescence on irradiation by black-filtered ultra-violet light.

Apparatus

For the investigations a table quartz-lamp S500 of the "Quarzlampen Gesellschaft mbH. Hanau/Germany" has been used. It is supplied with an ultra-violet black filter, which principally passes the strong mercury line of 366 mμ wavelength. The lamp does not differ particularly from other ultra-violet light sources commonly used in laboratories for fluorescence testing purposes.

Material

(1) Living fish and whole fresh fish undoubtedly still in *rigor mortis*.
(2) Whole fish frozen at sea on long-distance fisheries.
(3) Fish fillets frozen at sea and on shore.
(4) Fish fillets which have been frozen twice.

Tests were carried out on cod (*Gadus morhua*), coalfish (*Pollachius virens*), haddock (*Melanogrammus aeglefinus*), redfish (*Sebastes marinus*), catfish (*Anarrhichas lupus*), angler (*Lophius piscatorius*), halibut (*Hippoglossus hippo-*

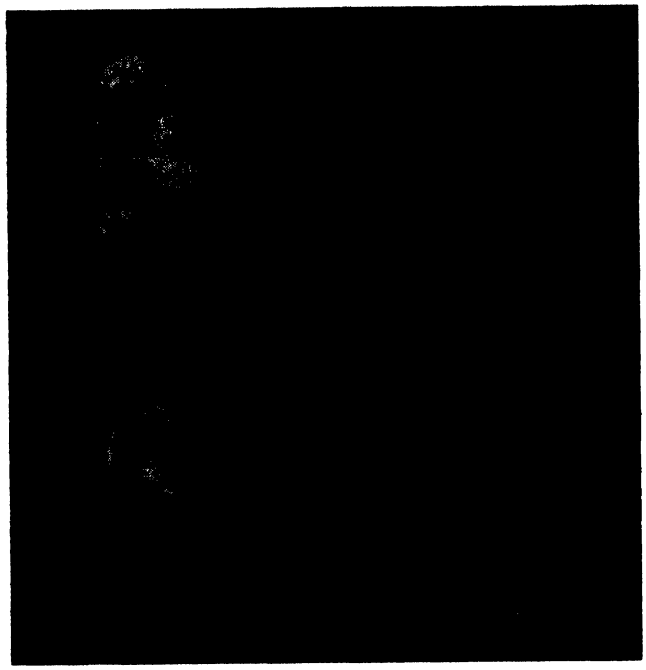


Fig 1. Cross-sections under ultra-violet light of a redfish frozen at sea during rigor mortis *(on the left) and of a redfish iced aboard a distant water fishing vessel (on the right)*

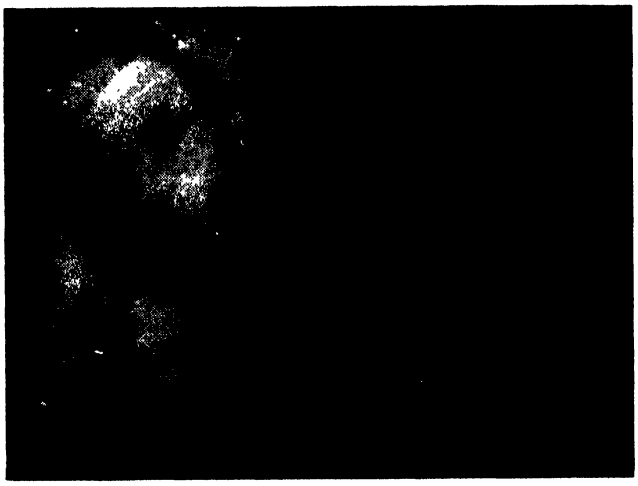


Fig 2. Cod fillets from fish blocks frozen at sea during rigor mortis *(on the left) and cod fillets from fish blocks frozen on shore after being chilled on board (on the right) under ultra-violet light*

glossus), plaice (*Pleuronectes platessa*), flounder (*Pleuronectes plesus*), smelt (*Osmerus eperlanus*), herring (*Clupea harengus*), mackerel (*Scomber scombrus*) and other species.

The fish tissue should be put under the quartz-lamp so that the ultra-violet rays meet it perpendicularly to its surface.

RESULTS

All living fish, fish in *rigor mortis*, fish and fish fillets frozen at sea, under examination, without exception showed the same characteristic blue-white fluorescence under black-filtered ultra-violet light of 366 mμ wavelength. The intensity of the fluorescence varied to some degree, being dependent principally on time and temperature of storage. Samples of cod tissue lost their fluorescence after 3 to 7 h at storage temperatures of about 18°C (64°F). If stored at 4°C (39°F) fluorescence disappeared after 6 to 12 h. Fluorescence remained the longest in the thickest parts of the fish muscle tissue, even for a short time after the relaxation of *rigor*.

If chilled fresh fish had already passed *rigor*, no fluorescence appeared. The same was true with fish and fish fillets which were chilled and allowed to pass *rigor* before being deep frozen on shore.

When fish fillets frozen in blocks at sea were thawed, packed and immediately refrozen, the characteristic blue-white fluorescence under ultra-violet light still appeared, but varied in intensity between individual fillets and some fillets did not fluoresce at all.

Fatty components in fish tissue, e.g. in redfish, catfish, halibut or in other fatty species showed a lemon-coloured fluorescence, the intensity of which increased during cold storage.

DISCUSSION

Lactic acid is present in fishes during life and during *rigor mortis*. Its presence can easily be detected by irradiation with black-filtered ultra-violet light of 366 mμ wavelength, which causes it to emit a characteristic blue-white fluorescence. The method can be used in determining whether or not fish has been frozen before or after the relaxation of *rigor*. With experience an operator may be able to estimate fairly closely at which stage of *rigor* the freezing took place. Thus the test will be quite valuable in reaching a decision as to whether fish has been frozen at sea or after bringing ashore, whether there has been a delay or mishandling of fish prior to freezing, or whether fish has been thawed and refrozen either during processing or as a result of equipment failure or poor refrigeration practice.

The characteristic lemon-coloured fluorescence of fatty components in frozen fish under ultra-violet light warrants further study as a possible method of estimating the length of time fish has been in cold storage.

DISCUSSION

Varela (Spain): Se exponen los resultados obtenidos en el Laboratorio de Fisiología Animal de la Universidad de Granada sobre la calidad de merluza frita congelada en panel entrenado.

Se explica la necesidad de conocer el proceso culinario como se ha preparado el alimento porque, por ejemplo, en el caso de la merluza frita, al estudiar la dinámica de la penetración de la grasa se ha visto que para comenzar la entrada de la misma durante la fritura, es necesario que salga previamente una cantidad determinada de agua. En la salida de esta agua juega poco papel la temperatura y mucho la textura y el tiempo del proceso. Por ello, la congelación del pescado al influir sobre la situación del agua del alimento condiciona la salida de ésta y por ello son probablemente difíciles de comparar los datos del panel obtenidos con merluza fresca y congelada, fritas a la misma temperatura.

Symons (U.K.): I use a taste panel system similar to that which Connell has outlined for fish and, although I use mine on peas, it could be adapted for fish. The feature my panel has, which

is a slight sophistication on Connell's, is that we use a computer to assess the results (differentiating variety, growing area, maturity, etc.) and also we calculate the bias of individuals, making the premise that the mean result of any panel is correct. The biases are calculated daily and individuals are considered trained (and therefore their results valid) when they have achieved a steady bias.

Connell (U.K.): I think Mr. Symons' remark that certain sectors of the food industry are using highly sophisticated taste panel techniques is most interesting. For many years there has been a resistance on the part of industry to use such techniques just because they seemed complicated. However, I believe that if one goes to the trouble of assembling people together for sensory testing, then the most should be got out of them. Therefore, I am very encouraged by the development he has outlined.

As far as bias within a taste panel is concerned, we do not yet go to the lengths of assessing bias every day or at every single taste panel session, but we do periodically review the performance of panelists and would certainly take individual bias into account. In the near future we hope, like Mr. Symons, to handle all our data processing arising out of taste panel sessions directly by computer and it will then be a simple matter to keep a continuous watch on bias and, of course, all other errors.

Holston (U.S.A.): The Gloucester Laboratory wanted a very highly discriminating taste-panel for a specific job. Each day we purchased quantities of very fresh haddock. We thereby built up a "library" of fillets stored on ice for different periods of time and on which we had complete histories as to handling and processing. We exposed staff members to groups of these fillets, identifying each group in terms of its age *post mortem* in days on ice. This initial indoctrination was continued until all members had established hedonic images for each group of fillets. We then included one unknown fish sample in the group and asked the panel to classify it properly as to days on ice. After repetition, the panel was graduated to two, three and more unknowns. After an exhaustive training session, all members were subjected to performance testing. We found only six out of a staff of 45 who could consistently (85 per cent of the time) classify an unknown fish sample correctly in terms of days (± 2) on ice. The mean of the select panels decisions was, in a series of tests, correct 100 per cent of the time (two days). We feel, as a result of much testing, that this technique can be of much help in rendering comparable taste-panel results in different laboratories.

Symons (U.K.): I was interested in Holston's point that only some six out of over 40 individuals could be trained to taste fish accurately. Published work generally supports the view that an overwhelming majority of people can be trained to taste most commodities and that it is training, not aptitude, which is important. Age of the individual taster is of course important, but only to the extent that it may be necessary to exclude people over about 55 years.

Kovacs (Federal Republic of Germany): Considering the definition of quality as the combination of characteristics differentiating between various units of a product and having significance in determining the degree of acceptability of the unit by the user (A. Kramer *et al.*, *Principles of Quality Control*, AVI, N.Y.), one wonders whether these most sophisticated methods—calculating bias, etc.—have any relation to the most important factor in the definition of quality—the user, i.e. the consumer.

Spiess (Federal Republic of Germany): As it was stressed just now, it is possible to educate a taste panel board to an extent that it will detect even small changes in a material, but I feel that it is very dangerous to express these changes in terms of organoleptic quality since it is well known, and also Kovacs has outlined this very clearly, that the expression "quality" refers only to the impression which a consumer receives from a product. So, for example, a fish product, which in northern Germany is regarded as a good product, is not accepted in southern Germany because of a lack of "flavour" or, in a more general term, "quality".

Dyer (Canada): We must carefully distinguish between an analytical taste panel, designed to measure comparative acceptability, from a consumer-type panel which requires much more extensive testing by a large number of people.

Foley (Canada): While taste panels serve a most useful purpose in the determination of quality at the production level, the members perhaps tend to become super-sensitive "consumers", but seemingly have less than the desired effect on the quality of fish reaching the real consumer, the housewife whose scoring sheet is non-computerized and quite simple, e.g. "good", "so-so", "never again" or if the processor is fortunate "better luck next time". Love observed that only three in 70 packages of fish tested in Northern Scotland had a quality equal to that of the fish leaving the processing plant. This situation is not at all unique to that part of the world.

It would, therefore, seem necessary to carry out more testing at the consumer level and to rectify the obvious insufficiencies in the distribution chain. We are merely playing games in producing high quality fish which doesn't reach the consumer.

Little (U.K.): The reason why only six people survived out of a panel of 45 is that tasting of fish is not easy and enthusiasm wanes quickly especially with young people—dedication is required in a fish taster.

It seems to be felt that any well-run laboratory should include taste panels in all its experiments. This results in a large number of panels per day and causes great dissatisfaction amongst those on the panels. I believe that we must get rid of taste panels—they produce too much confusion and do not allow us to compare inter-laboratory results. Objective tests are the answer and I believe that tests such as Sutton's texture meter and the Torry hypoxanthine test give us the tools to draw up objective limits for specifications and inter-laboratory discussion.

Banks (U.K.): I think Little has made a very important point. I was wondering myself when we would get round to discussing this question of objective tests. There is another aspect to this question. In cases of checking quality I wonder how far the taste panel test is going to be accepted in the sort of semi-legal positions that might arise?

Sørensen (Denmark): Objective measures of eating quality cannot be generally applied as a basis for quality control systems in industry. Each processor must develop his own systems for control. For instance, the rate of spoilage will often vary very much between fish caught on the same grounds. No universal system is possible. When talking of the eating quality of the frozen goods, objective measures could eventually be agreed upon, but this is only one of several quality factors. Such methods would never come into use as a means of settling a dispute between buyer and seller on the quality of a shipment. The buyer is always right. Complaints are many when stocks are high, but very few when frozen fish products are scarce. I cannot, therefore, see the need for these recognized overall objective methods and do not believe they will ever be achieved.

Varela (Spain): Precisa que quizás conviniera fijar conceptos en cuanto a las pruebas organolépticas.

Según es sabido, para conocer la aceptación por los consumidores se utilizan ensayos en muestras representativas,

precisamente de consumidores normales, no seleccionados. A nosotros nos resultan útiles y económicas las pruebas de aceptación realizadas en colegios universitarios o profesionales.

En el Laboratorio y dentro de la técnica del panel se pueden utilizar la de diferenciación, en la que se utilizan catadores seleccionados y en general entrenados para las pruebas organolépticas y el llamado panel analítico en el que los catadores se seleccionan y entrenan precisamente para un problema concreto. Por ejemplo, en nuestro caso el panel analítico dictamina sobre la clase de material de que está hecha la vasija en que se frió el pescado o la presencia de un determinado antioxidante en la grasa de fritura.

En nuestra opinión la técnica del panel semientrenado es la más idónea para la industria.

Malick Dia (Senegal): J'interviens, Monsieur le Président, sur le problème particulier du contrôle de la qualité principalement parce que nous sommes des exportateurs et des clients de pays difficiles où, si l'on en juge par les méthodes de contrôle qui nous ont été presentées ici, nous serons victimes du coefficient de subjectivité des membres des différents jurys de dégustation.

J'appréhende en effet que le simple fait pour eux de savoir que le produit à apprécier est d'origine africaine, aura déjà une influence psychologique qui faussera toute appréciation.

Nous avons donc des raisons de nous méfier de ces méthodes plus ou moins empiriques qui peuvent nous léser quand en Europe on apprécie nos produits.

Par contre les éminents hommes de science qui se sont succédés sur cette tribune nous proposent des méthodes de mesures objectives qui sont susceptibles d'être employées aussi bien par nous qui sommes les contrôleurs des industries de poisson, que par nos confrères qui jugeront ce poisson à leur arrivée dans les pays importateurs.

Je crois sincèrement qu'une des raisons d'une réunion comme la nôtre est de pouvoir faire des recommandations aux différents techniciens, compte tenu des résultats scientifiques connus, pour le choix de telle ou telle méthode.

Un des rôles de la FAO devrait être précisément de tenter de coordonner tout cela afin d'établir une liste des méthodes objectives qu'on pourrait utiliser pour l'appréciation de la qualité du poisson et de poser le problème de la normalisation de ces méthodes.

Simmons (U.K.): The use of objective quality assessment of fish in place of laborious taste panel work depends upon a good correlation between the objective method and subjective organoleptic method. The papers by Jendrusch and Kietzmann place emphasis on total volatile bases and indeed state that T.M.A. does not satisfactorily correspond with organoleptic ratings. It is important that the various scientific bodies throughout the world should at least agree on the acceptable organoleptic methods for freshness determinations of the various main fish species.

Kelly (U.K.): I think we are all in favour of objective methods for determining quality but we must tread warily in certain areas on objectivity, where national preferences might exist. An example of what I have in mind has arisen in some of the papers at this meeting. I refer particularly to those in which storage of redfish has been mentioned. Tilgner's paper in Part I and Kietzmann's paper today mentioned that redfish are particularly susceptible to the development of off-flavours, when held in cold store, with a storage life limited to a few months. On the other hand, MacCallum in his paper states that he was able to store redfish for periods in excess of one year. We must assume that the same chemistry goes on in redfish whether they are stored in Canadian or European cold stores so presumably some flavours which are acceptable in Canada may be unacceptable in Europe and an objective test, which passed a fish in Canada, would damn the same fish in Germany. It is probable that any objective method developed for redfish flavour might have to have different limits in different countries depending on national taste preferences.

MacCallum (Canada): I find Kelly's remarks on the difference on the appraisal of redfish quality in Germany and in Canada most interesting and worthy of follow-up. On the other hand, data reported in our paper in Part I of this Conference do show depreciation of redfish in both texture and taste during frozen storage at --23°C (−9°F), a fact not brought out in Kelly's observation.

Soudan (France): Nous avons étudié l'évolution de l'hypoxanthine chez différents poissons selon la méthode proposée par Jones. Les nucléotides séparés par deux types de résine sont dosés par absorption dans l'ultra-violet.

La manière dont le taux d'hypoxanthine augmente pendant la conservation diffère suivant les espèces. Chez le merlan, l'hypoxanthine croît proportionnellement au temps comme indiqué par Jones alors que chez la sardine elle croît tardivement et à peu près comme la triméthylamine.

Il semblerait donc que le dosage de l'hypoxanthine comme test de l'état de fraîcheur du poisson soit moins général qu'on aurait pu l'espérer.

Dyer (Canada): We (Fraser, Simpson and Dyer, unpublished) have recently noted an exception to the hypoxanthine *vs.* quality picture. In each of four separate lots of redfish (ocean perch—*Sebastes marinus*), iced from one to three days on the vessel, the initial hypoxanthine content was high, 1 to 2.5 μmoles/g, and rapidly reached its maximum level at about 72 hours after catching. In striking contrast to the data just presented in the above paper by Burt *et al.*, the quality of the raw and of the cooked fish at the time when hypoxanthine levels had reached their maximum was still very high, indistinguishable from freshly caught quality.

Jones (U.K.): I would like to comment on the point raised by the previous speakers concerning the status of the hypoxanthine test. This relates to (a) time of storage and (b) organoleptic rating. On point (a) the vast majority of species so far examined show good correlation between time of storage and hypoxanthine concentration. On point (b), correlations between concentration and panel evaluation have generally been very good for lean, white fish. Semi-fatty fish have been variable in this respect. Correlation between panel evaluations and fatty species has often been poor. This possibly reflects the relative organoleptic importance of factors such as nucleotide breakdown (and hence hypoxanthine formation) in the context of others such as fat oxidation, the presence of enhancers, maskers and so forth.

With regard to the relative performance of hypoxanthine and TMA testing, I would just point out that data were presented in the original paper on relative performance on commercial fish in the Humber ports. They were similar. On fresher fish hypoxanthine has the edge.

One other point occurs to me. The method now presented is, as we have seen, quite simple. It does occur to me, however, that the enzyme may be difficult to obtain or expensive in some countries. I would point out that an early simple silver precipitation technique exists. This has been used successfully by Simahiya *et al.* for control measures on South-west Atlantic species and as hake.

One could elaborate at length on the point of objective measures of flavour, as distinct from texture. Suffice it to say that there is now a considerable amount of information available on the flavour chemistry of fish and that this is available in review form. The information available to us under-rates clearly that no single chemical test can monitor flavour changes under all conditions.

Sutton (U.K.): We have found an excellent agreement between the hypoxanthine content in cod muscle and days storage on ice.

The problem with most objective tests is that they are destructive. Only a small percentage of the fish processed can be sampled since the muscle is then discarded. However, cooked textural properties of species such as cod vary between the individual fish, and cannot be assessed for a batch as a whole by examining small samples from the batch. This can only be done by measuring some property of each and every fish, such as by the use of the Henning's fish tester or the automatic pH grading machine being developed by us.

Spinelli (U.S.A.): In dealing with frozen fish, I believe that not too much emphasis should be placed on the hypoxanthine determination alone. It should be remembered that in the nucleotide degradation scheme, two enzyme systems are at work. First, nucleosidases degrade the 5'IMP to inosine and inosine is then subsequently degraded to hypoxanthine and ribose by riboside hydrolase. The rates at which these enzymes attach their respective substrates are different. It is possible therefore to have practically no 5'IMP and also very little hypoxanthine in the same fish. This actually happens with our Pacific cod. Since it is the 5'IMP that is implicated with changing fish flavour, both IMP and hypoxanthine should be determined simultaneously on frozen fish. The methodology is sufficiently advanced and simple that this would not present a problem for those who are sufficiently interested.

Bligh (Canada): I would like to inform the meeting of our results with the hypoxanthine test on fresh-water fish.

A limited number of tests on iced pickerel (*Stizostedio vitreum*) and fresh-water whitefish (*Coregonus clupeaformis*) have shown that the average hypoxanthine content is proportional to the number of days in storage. There was variation between individual pickerel but average values gave a good index of freshness.

Tomiyama (Japan): As to the discordant results between hypoxanthine value and taste panel, it may be supposed that this discordancy is due to the difference in the enzymatic activity responsible for yielding hypoxanthine. From our experience, we noticed that quite a marked difference in adenine or adenosine deaminase among various kinds of fish. So, it is not pertinent to extend knowledge of a quality index based on hypoxanthine value obtained for cod to judge the quality of other fishes and to relate it to the taste panel score.

I would like to make another comment on the relation between the hypoxanthine quality index and TMA or TVA values. In this respect, it is important to know that the formation of hypoxanthine mainly results from the tissue enzymes, while the TMA or TVA mostly result from microbial contaminants except for some ammonia produced by the adenine or guanine deaminase. It is, therefore, not surprising if there is any discrepancy between these two quality indices.

PART V

STORAGE, PACKAGING AND DISTRIBUTION OF FROZEN FISH PRODUCTS

DESIGN AND OPERATION OF COLD STORES

Design and Operation of Cold Stores for Fishery Products *G. Lorentzen*

Trends in Building Design, Especially Prefabricated Section Construction . . . . . *P. O. Persson*

La protection des isolations contre la pénétration de la vapeur d'eau . . . . . *P. Clément*

Discussion

PACKAGING AND DISTRIBUTION OF FROZEN FISH PRODUCTS

Envasado de Pescado Congelado . . . *L. Sicre*

Experience with Modern Packaging . *C. A. Almarker*

State of the Art and Problems of Frozen Fish Packaging *R. Heiss*

Transport of Frozen Fish . . . *M. A. Foley*

Discussion

Design and Operation of Cold Stores for Fishery Products

by G. Lorentzen

Design and operation of cold stores for fishery products

In principle a cold store for fishery products is not much different from one for any other type of commodity. Its integration into the general layout of a production plant is very important, however, and is discussed on the basis of a few examples. Modern development of mechanical handling systems has brought important changes to the design of freezer stores. High ceiling rooms for lift truck operation are now common for all plants of reasonable size, and some important considerations in their planning are brought out.

The building structure has the sole purpose of providing protection for the insulation and equipment with due consideration of aesthetic aspects. Prefabricated section design is constantly gaining ground. Rapid development is taking place in insulation materials and their application. Some important data for a number of modern materials are given and the moisture migration problem is discussed. The requirements for floor finishes have increased with the use of heavy transport equipment. Proper battens are necessary to prevent stowage right up to the walls in non-jacketed rooms. Freezer room doors often give difficulties, and new, promising designs are now appearing on the market.

Fish storage requires lower temperatures than most other foods, and this affects the design and dimensioning of the refrigeration system. The wet nature of the raw material leads to extra stresses on the buildings and difficult sanitation problems. The traditionally rough treatment of all equipment in the fishing industry calls for simple and robust design. Altogether it must be stressed that cold stores for fishery products require great care and experience in planning and operation to achieve satisfactory results.

Conception et exploitation des entrepôts frigorifiques pour produits de la pêche

En principe, l'entrepôt frigorifique destiné aux produits de la pêche ne diffère guère de l'installation conçue pour d'autres marchandises. Sa place dans l'agencement d'ensemble de l'usine est toutefois très importante, et elle est étudiée à l'aide de quelques exemples. La récente mise au point de nouveaux dispositifs de manutention mécanique a entraîné d'importantes modifications dans les plans des entrepôts frigorifiques. Dans tous les bâtiments d'une certaine taille, on trouve maintenant couramment des chambres très hautes de plafond, qui permettent l'emploi de chariots élévateurs. La communication traite de certaines considérations importantes concernant leur organisation.

La structure du bâtiment, compte dûment tenu de l'esthétique, a pour seule but de fournir une protection aux matériaux isolants et à l'équipement. L'emploi de sections préfabriquées gagne de plus en plus de terrain. Le domaine des matériaux isolants et de leurs applications se développe rapidement. La communication fournit certaines données importantes touchant plusieurs matériaux modernes, et examine le problème de la diffusion de l'humidité. L'emploi de matériel lourd de transport impose de nouvelle exigences pour les revêtements de sol. Des lattis sont nécessaire pour éviter que les piles de marchandises ne s'appuient au mur dan les chambres n'ayant pas de double paroi. Les portes des chambre de congélation posent souvent des problèmes et des modèle nouveaux et prometteurs commencent à apparaître sur le marché.

Le stockage du poisson requiert des températures plus basses que la plupart des autres denrées alimentaires, ce qui affecte la conception et les dimensions du système de réfrigération. L'humidité de la matière première impose aux bâtiments des servitudes supplémentaires et pose de difficiles problèmes d'hygiène. Tout le matériel employé dans l'industrie des pêches, étant donné le rude traitement auquel il est soumis, doit être simple et robuste. Les entrepôts frigorifiques destinés aux produits de la pêche exigent beaucoup de soin et d'expérience aux stades tant de la conception que de l'exploitation.

Construcción y funcionamiento de cámaras frigoríficas para productos pesqueros

Una cámara frigorífica para productos pesqueros no difiere mucho, en principio, de cualquier tipo de producto; su integración en la estructura general de una fábrica es, en cambio, muy importante, y es discutida recurriendo a algunos ejemplos. El moderno desarrollo de los sistemas mecánicos de manipulación ha ocasionado importantes cambios en el diseño de las cámaras frigoríficas. En todas las instalaciones de cierto tamaño son ahora usuales locales de techo elevado, para permitir el empleo de las carretillas elevadoras, y se exponen algunas importantes consideraciones sobre la forma de proyectarlas.

La estructura del edificio no tiene otra finalidad que proporcionar protección al equipo y aislamiento, sin descuidar los aspectos estéticos. Los proyectos de sección prefabricada continúan ganando terreno. Los materiales de aislamiento, y sus aplicaciones se están desarrollando rápidamente. Se dan algunos datos importantes sobre algunos materiales modernos y se discute el problema de la migración de la humedad. El acabado de los suelos, a causa de un pesado equipo de transporte, exige un mayor número de requisitos. Hacen falta panas que impidan que el material almacenado llegue a tocar las paredes de los locales aislados. Las puertas de los frigoríficos presentan frecuentemente dificultades y en la actualidad están apareciendo en el mercado nuevos diseños prometedores.

El almacenamiento del pescado exige temperaturas más bajas que casi todos los demás alimentos, lo cual afecta a las formas y a las dimensiones del sistema de refrigeración. La materia prima, por su humedad, ejerce tensiones extra sobre los edificios y plantea difíciles problemas sanitarios. El duro tratamiento que tradicionalmente se inflige a los equipos de la industria pesquera exige una concepción robusta y sencilla. En conjunto, debe ponerse de relieve que la preparación y el funcionamiento de las cámaras frigoríficas para los productos pesqueros requieren gran experiencia y gran cuidado, si se quieren conseguir resultados satisfactorios.

FISH products are stored in a fresh or frozen state. The fresh fish trade is traditionally separate from other food distribution lines. Separate storage rooms and transport equipment must be used to avoid taint due to the nature of the product. With frozen products conditions are radically different. At modern low-storage temperatures fish can be held and transported together with other frozen commodities. The trend is to handle all frozen foods through a common freezer chain. Frozen fish are handled in general commercial cold stores and cause no particular design requirements, except that the temperature must be sufficiently low. There is a rapid development to freeze an ever-increasing part of the catch.

Fresh fish are usually kept in ice, and the function of cold storage rooms and refrigerated transport equipment is to reduce melting and further improve keeping quality by eliminating the effect of high outside temperatures. There are no particular problems of equipment design, and improvements in the trade must be reached by better and more economical application of well-known principles and established practices. Technological develop-

ment in this field is exceedingly slow and does not merit much discussion in this paper.

When it comes to freezing, the situation is different. The technology is in a state of rapid evolution, and a discussion on various aspects of design and operation of fish processing plants seems indicated. This will include to some extent the processing, freezing and storage sections of such establishments. Conditions in general cold storage and the freezer chain, which are common to all frozen foods, will not be discussed in this paper.

ARRANGEMENT OF THE PLANT

Choice of site

The choice of a suitable site for the freezing plant is a decision of crucial importance to the efficiency and future economy of operation. One of the most important conditions for success is the efficient transport of goods to and from the plant.

A regular supply of good quality raw material in sufficient quantities is an obvious requirement which, surprisingly enough, is not always fulfilled. Many are the cases of over-optimistic forecasts on this point in the fishing industry. Direct and rapid transfer of fish into the plant is extremely important not only with regard to economical handling but also from a quality viewpoint. In the case of direct supply from fishing vessels or transport ships the workrooms and buffer store should preferably be placed directly at the receiving pier, which must have sufficient water even at low tide, and good weather protection. It is advantageous that other services such as icing, oiling and provisioning, are available at the same or a nearby location.

In ports where the traditional auction system is practised, conditions for the fish packing plants are different in that the raw materials are usually brought in overland. The location should, of course, be as close to the auction as possible for rapid transfer. With a view to the quality loss by the extra time and handling and the costs involved, it would seem that the auction system in the old form, actually over the fish, should gradually be abandoned. With this in mind it would be wise to try to locate any new plant with due regard to efficient direct delivery over its own pier.

With regard to the shipment of the products, whether iced fresh fish, frozen fillets or in other forms, similar conditions prevail. Rapid transfer of large lots is required, and this must be borne in mind in laying out the rail sidings, truck ramps or shipping piers. The rapidly increasing importance of truck transport and the steadily growing size of trailers has greatly expanded the demand for manoeuvring and parking area adjacent to the plant. It is very common that the yard space requirements have been grossly under-estimated, even for very recently constructed plants.

Other important considerations in choosing the site can be listed as follows:

good and stable building ground at a reasonable price;

ample space for outdoor storage and future expansion;

sufficient supply of clean fresh water, condenser water and electric power at reasonable cost and regularity;

availability of labour;

sufficiently good communications;

availability of technical and commercial services.

These conditions will normally be filled to a greater or lesser extent for different locations. The final choice should only be made on the basis of a sufficiently detailed estimate of building and operating costs for all possible alternatives. Obvious as this would seem, examples are not hard to find of plants built at unnecessarily high cost or with unpractical and expensive transfer operations due to an unsuitable choice of site.

General layout

The general arrangement of a plant depends naturally to a very large extent on the nature of its activities. Due to variations of the supply of raw materials and market conditions, flexibility to change production accordingly is extremely important. Experience shows that this is most readily achieved with a clear and simple layout of the various departments. This is also a great advantage in construction, particularly when modern light structures and prefabricated sections are used (Persson, 1963).

With the very great variations of conditions it is only possible to illustrate the principles by a few examples. Fig 1 is the general arrangement of a simple fresh fish packing plant. The work on the product is very limited, time is essential and efficient transport arrangements for the fish going through the building is of primary impor-

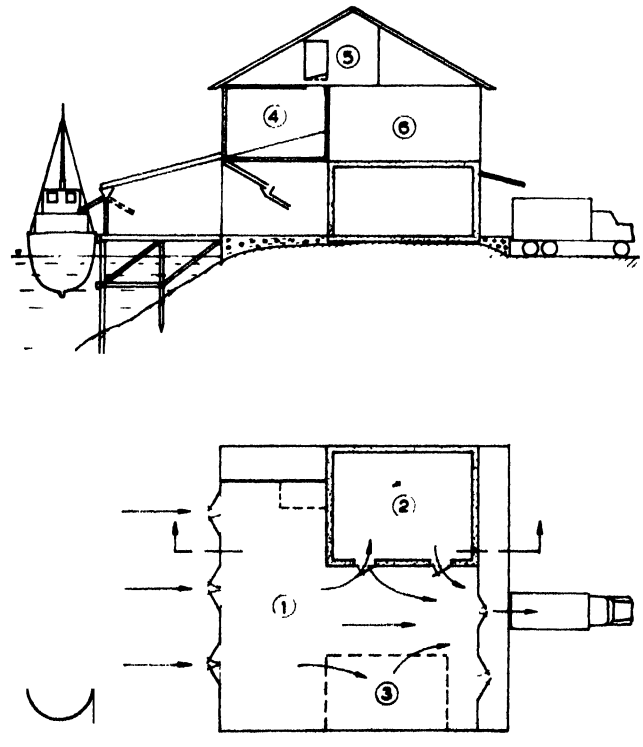


Fig 1. General arrangement of a small fish packing plant. (1) Washing, gutting, trimming, packing, etc. (2) Cold storage. (3) Salting. (4) Small-ice storage. (5) Ice maker. (6) Storage of packaging materials, salt bins, etc.

tance. The fish are unloaded at the pier directly from the boats, washed and in some cases gutted and trimmed, and then packed in ice. Sometimes filleting, salting or drying is also done, depending on fish species and market conditions. Refrigerated rooms should be available for short-time storage before shipment. In large operations it may be rational to have an ice-making plant and ice store, which can be placed in such a way that the ice is transported by gravity to the various places where it is used and for delivery to the boats. Further space should be available for storage of packaging materials, salt, etc.

The design of a freezing plant is necessarily much more complicated, depending on the diversity of its activity. When raw material is bought at the auction or where the fishing is limited to one general type of fish, production can be concentrated on a single line and the plant layout becomes comparatively simple (fig 2). Raw material is

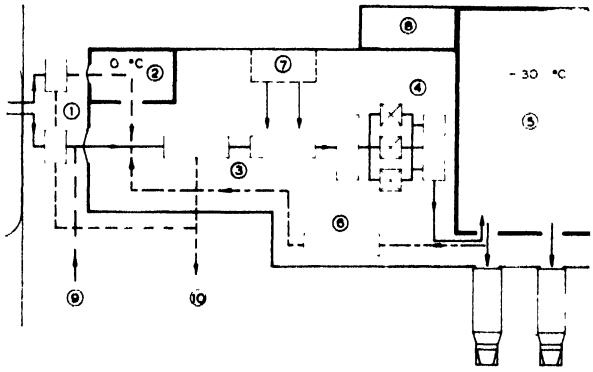


Fig 2. Small plant for single-line production of frozen fillets. (1) Reception, gutting, washing, weighing, etc. (2) Cold storage raw material. (3) Filleting and packaging. (4) Freezing. (5) Freezer storage. (6) Thawing of frozen raw material. (7) Preparation of packages. (8) Refrigeration machinery. (9) Raw material from auction. (10) Offal out

delivered to the processing line directly or via a refrigerated buffer store. Sea frozen raw material is used more and more in some countries. This has the great advantage that it can be stored for long periods to even out production. After processing, i.e. filleting and packaging, the fish are frozen in special freezers and taken into cold storage. The offal should be processed to mink food, oil, meal, etc. In small operations it may be more economical to do the offal processing at a central, special plant.

Planning is much more difficult where conditions are such that the plant must take all the products of a diversified fishery. It may be necessary to operate a number of processes such as fresh fish packing, salting, drying, several lines of filleting, freezing, and offal processing, etc. At the same time the plant may have to serve as a supply base for the fishing fleet. The layout must be a compromise of conflicting interests, and the greatest possible flexibility is necessary to change production in accordance with seasonal variation. The product flow diagram for a typical plant is shown in fig 3 and the general arrangement in fig 4. The design must be based on a very careful analysis of the actual conditions to be expected, and will vary greatly from one case to another.

The frozen products are usually stored at the plant for some time before shipment. It is seldom economical to transfer the products directly from freezing to a general cold store unless this can be built directly adjacent. After leaving the plant, possibly via a central freezer store at a shipping centre, the products usually go into a general freezer chain and are stored together with other commodities. Due to the especially strict temperature requirements for fish it is absolutely necessary to maintain a rigid control of conditions and particularly storage times. The plant should be constructed with a layout to facilitate the practice of the "first in first out" principle. Experience

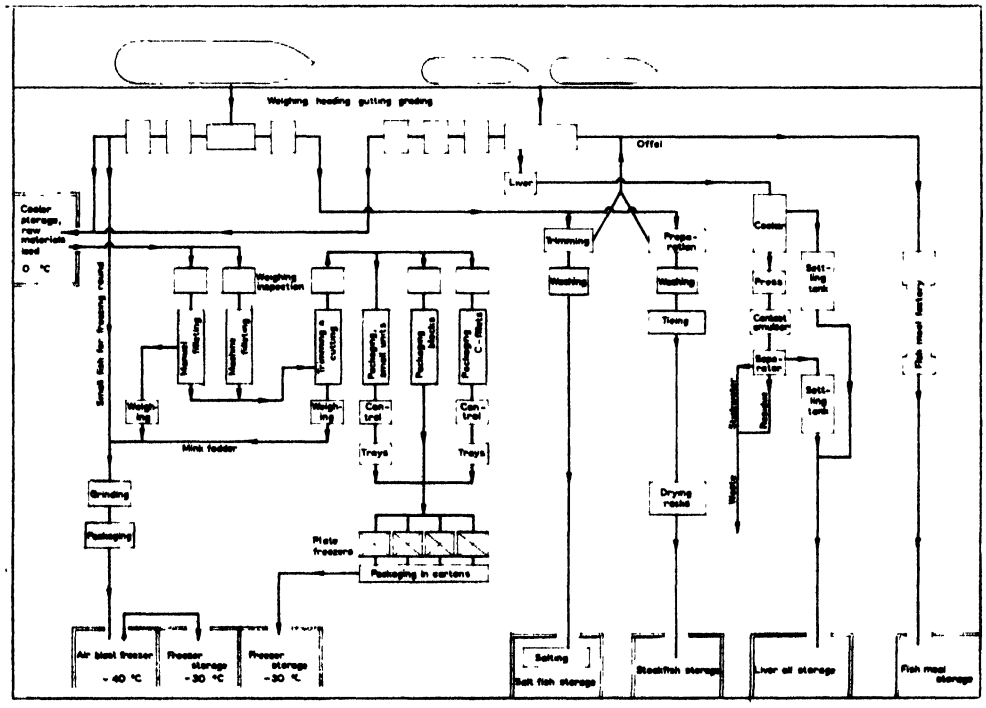


Fig 3. Product flow diagram for a general fish freezing and processing plant. Great flexibility of operation is essential to adjust the production pattern to seasonal requirements

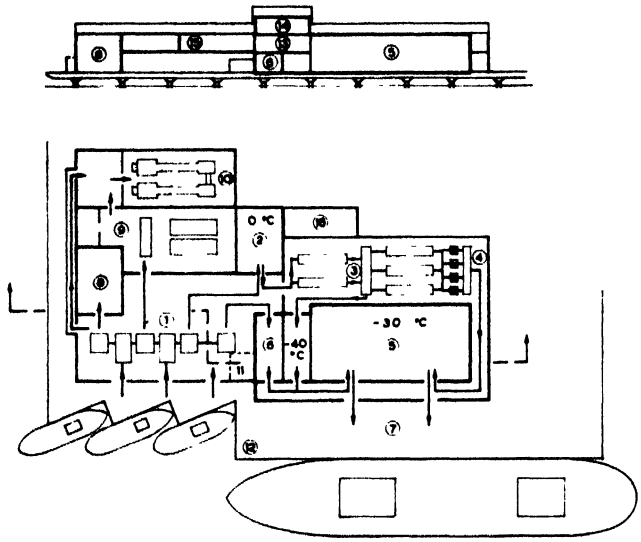


Fig 4. Simplified layout of a fish freezing plant with a product flow diagram as indicated in fig 3. (1) Gutting, washing, weighing, icing, etc. (2) Cold storage raw material. (3) Filleting and packaging lines. (4) Freezing and packing in cartons. (5) Freezer storage. (6) Freezing tunnels for mink fodder and raw material. (7) Shipping quay. (8) Liver oil plant. (9) Preparation for salting and drying. (10) Reduction plant. (11) Ice bin. (12) Ship icing station. (13) Ice storage. (14) Ice-making plant. (15) Storage packaging materials, salt bins, offices, canteen, etc., on first floor. (16) Refrigeration machinery

Fig 5. Typical multi-purpose fish freezing and processing plant in northern Norway

shows that there is considerable risk of having some products remain too long in storage, leading to uneven quality in the trade (Lorentzen, 1962–63).

Like so many other activities fish processing is to a very large extent transportation, i.e. movement of raw material, offal, packaging materials and final products. Good planning is really the efficient solution of a succession of transport problems. Much depends on how the goods go into the plant and out of it. Vertical transports by lifts or hoists are generally slow and uneconomical, and the modern tendency is to a one-floor design for the whole plant. In order to utilize the storage area efficiently relatively high piles up to 6 to 7 m is generally practised, using fork lift trucks. It is often advantageous to place rooms for storage of process materials, i.e. ice, salt, packaging materials, etc., on a higher level, so that these can be supplied by gravity at the exact point where they are needed in the process.

There are exceptions to the tendency of horizontal planning. The unloading and loading of ships usually involve vertical transports in any case. When the bulk of the goods is going both in and out by ship, arrangements for processing and storage on several floors may be economical. Any floor may be served directly by crane via platforms, and transports from higher to lower levels can be done easily and efficiently by gravity chutes. Fig 5 can give an impression of a typical multi-purpose fish processing plant designed with several floor levels interconnected by internal conveyors.

Mechanical handling

It will be clear from what has already been said that the transport equipment is of primary importance to the efficiency of any fish plant and greatly affects its general layout. It may be said that the plant should be built around the selected transport system. The post-war years have seen a rapid development in this field, and the conception of the buildings has changed accordingly. One typical aspect of this evolution is the trend towards high ceiling, one-floor arrangements, using efficient horizontal conveyors and mechanical stacking equipment. The degree of mechanization must naturally depend on the cost and availability of labour and other local conditions.

Obviously the choice of transport equipment depends to a large extent on the volume of goods to be handled. In a small packing plant producing a few hundred tons of fish per year, an elaborate mechanical transport system will not pay its way. It is more economical to use hand trucks and manual stacking, and the cold storage rooms should be built with a moderate height of somewhat over 2 m in accordance with the old practice. For larger capacity stores conditions are radically different, and mechanical handling is a necessity.

Nearly all larger freezer storage rooms today are built for palletized operation, and the design is largely decided by the possibilities and limitations of the fork lift truck or reach truck (fig 6). The layout starts with the drafting of a pallet plan for efficient utilization of the floor area. The most commonly used pallet size is probably the standard 100×120 cm (40×48 in), but the product package dimensions may impose other non-standard sizes in some cases. Morphew and Jones (1966) recommend the following principles to be observed:

(1) The depth of stow that an efficient reach truck driver can reasonably negotiate is seven, and this is aimed at as a maximum. Special circumstances, however, such as the shape of the site, can push this up to eight or even nine. Thus 14 deep stows are generally planned, served by gangways from both sides.

(2) A careful analysis of the different quantities of the various products to be stored can increase utilization. The planning of all stows at seven or more deep can waste space when there are products requiring less, which should not be over-stowed. In these circumstances it is a good plan to have a stow of seven served by a gangway on both sides; the cold store manager can then have any

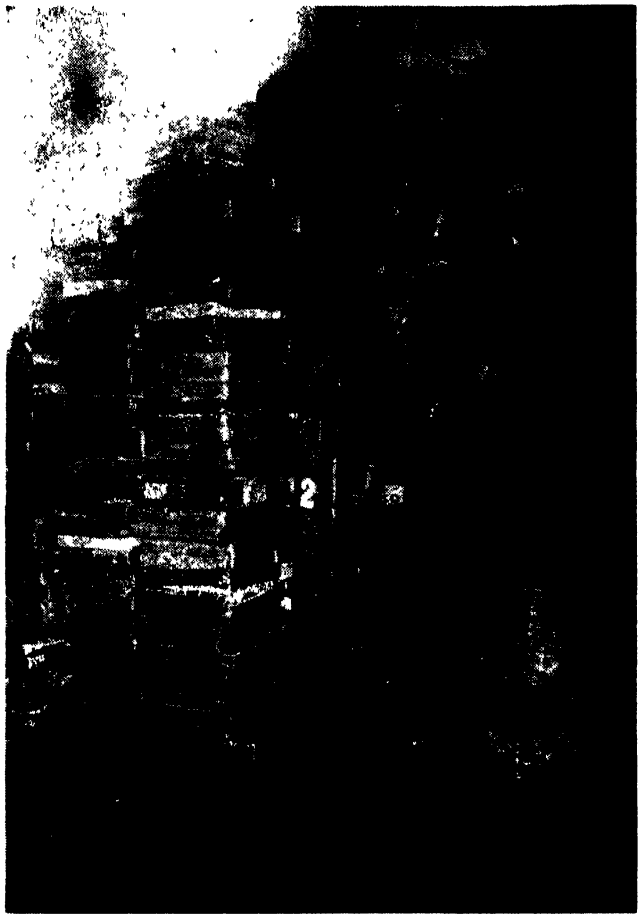


Fig 6. Fork-lift truck at work in a freezer storage room at −30°C (−28°F)

permutation within this number to accommodate his smaller volume lines.

(3) An allowance has to be made between pallets for manoeuvring and it is adequate, but only just, to allow 8 cm (3 in) between pallet stows, and 5 cm (2 in) between each pallet in that stow (fig 7).

(4) Gangways should be about 2.60 m (8½ ft) wide for reach trucks, and should be kept at a minimum. However, even with careful planning, the ultimate management of the store can produce a requirement of eliminating, adding, or even altering the position of connecting gangways. It is therefore a good plan that connecting gangways have dimensions conforming to multiples of pallets and their intermediate spaces.

The price per unit storage capacity is less the higher the room can be made. There is therefore a great economic advantage in high stacking, and the trend has been towards ever higher rooms over the last few years. The limit is set by the design of the lift trucks and their ability to operate safely at high levels. Presently rooms with 6 to 8 m ceilings are common, and it is doubtful whether it is possible to increase this much further without radical changes of present techniques. Larger size pallets may provide a possibility in this direction. For some products and packaging it is necessary to relieve the pressure in the tiers by use of special corner stanchions on the pallets or similar arrangements.

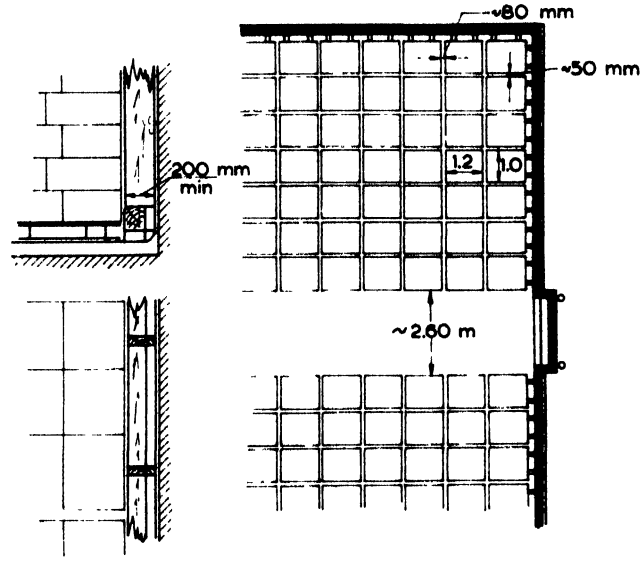


Fig 7. General pallet plan arrangement for a freezer store. Detail showing arrangement of kerb and battens to maintain necessary airspace between wall and stack of pallets

Even in palletized operations the labour costs in handling are considerable, and much work has been done to develop so-called "automatic stores". A few such designs are now in operation in the United States. They may have advantages under conditions where the turnover of goods is extremely rapid. It seems clear, however, that the loss of effective storage space is so high with the present systems that they will be uneconomical for general cold storage. It is believed that the general pallet lift truck operation will be the standard method for many years to come.

DESIGNING THE BUILDING

Structure

Having decided the dimensions and general layout of the store, one can concentrate on designing the building. The only two factors in the construction of the cold store itself that contribute directly to the task of maintaining the required temperature are insulation and refrigeration machinery. These two should be balanced to give optimum economy to the user. All other items should be designed to do their functions at a minimum investment cost.

The object of the building structure as such is only to provide protection for the insulation and support for the roof, floors and technical equipment. Stability, air tightness and high vapour diffusion resistance are important factors. The external appearance of the building must be taken into account in choosing materials and design features. Expensive masonry and poured-in-place concrete construction is steadily giving way to pre-formed concrete or steel (figs 8 and 9). These lighter structures are also much quicker to erect, and this is also an important consideration.

One particular insulation material has sufficient structural strength to allow elimination of any outside

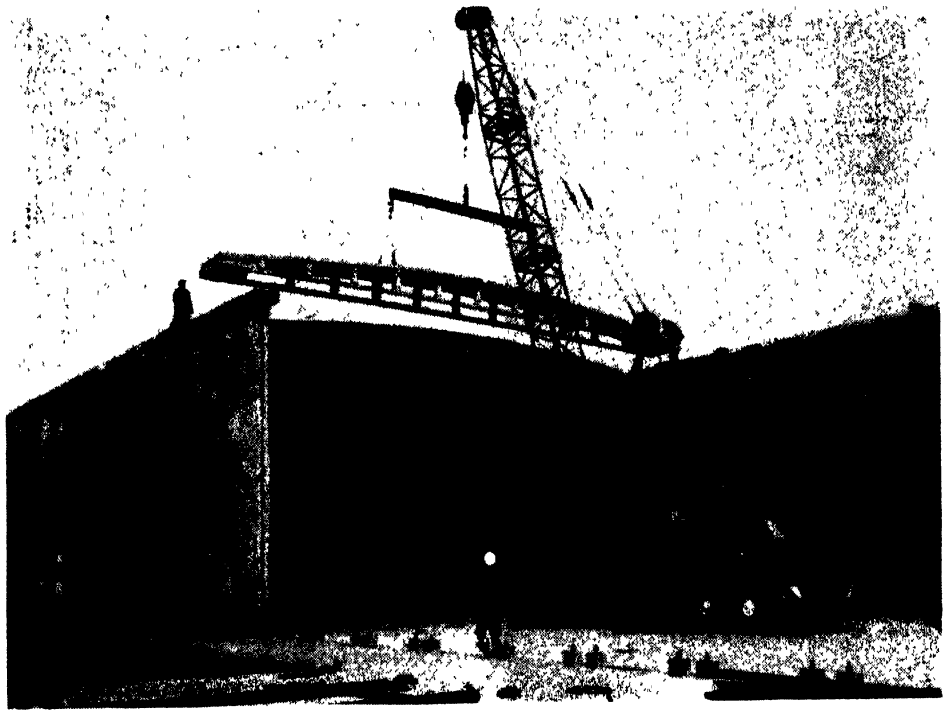


Fig 8. Freezer store under construction from precast concrete sections

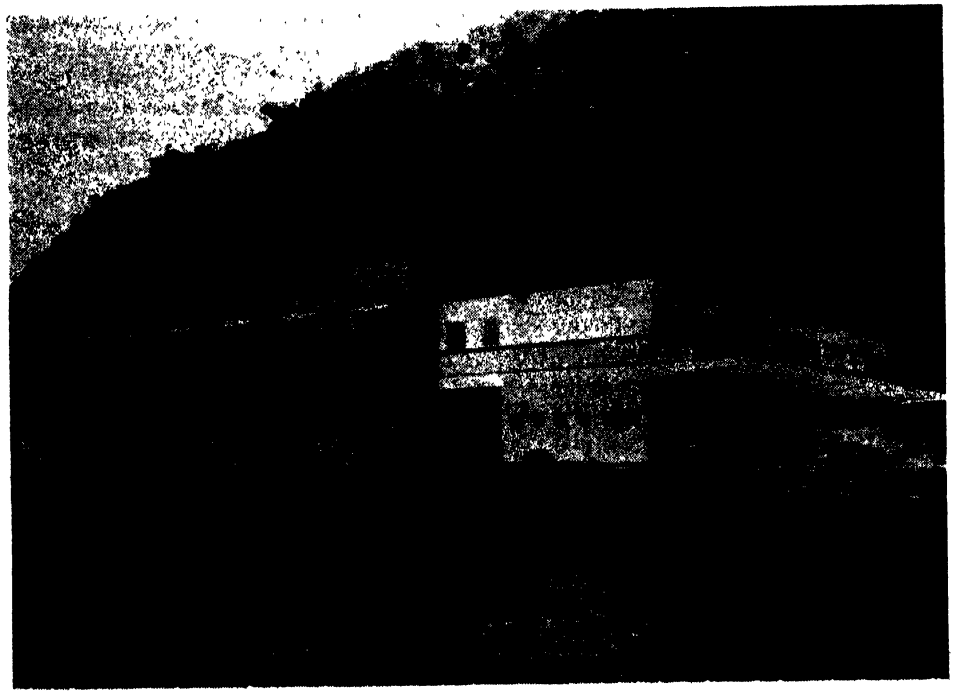


Fig 9. New fish freezing and storage plant in Norway, constructed from special corrugated steel panels

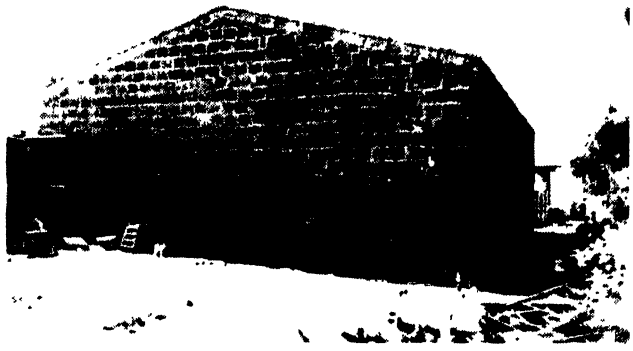


Fig 10. Freezer store being constructed of foamglass blocks acting simultaneously as structural material and insulation. No extra outside wall or vapour barrier is required

cladding, and is also completely moisture proof. This makes possible an exceptionally simple cold store design, which may be economically advantageous under favourable conditions (fig 10).

Storage temperature

Fish products are very perishable and the storage temperature requirements are correspondingly stringent. Chilled produce should generally be stored close to the freezing point. For fresh fish of the hypotonic type this means about −1°C (+30°F) while isotonic fish such as sharks and skates start freezing at −2° to −4°C (+28.4° to +24.8°F). For salted products the temperature may be reduced further without freezing. Some data of recommended temperature and expected commercial storage time are recorded in table 1. It has to be realized, however, that conditions are extremely variable in practice due to differences in the conditions of the fish and its treatment, and there is no substitute for experience. The quality drops steadily during the storage period and the decision of when it is no longer acceptable depends greatly on the habits of the consumers in the particular region. This is the main reason for the very variable data on keeping times given in the literature for the same species of fish.

TABLE 1. COOL STORAGE CONDITIONS FOR SOME FISH PRODUCTS

Commodity	*Temperature (°C)*	*R.H. (%)*	*Expected storage life*
Fresh fish in ice, depending on species, condition and market requirements	−1 to 1	100	5 to 20 days
Salt lean fish	−2	80–85	10 months
Salt herrings	−2	90–95	12 months
Klipfish	2 to 4	75–80	12 months
Caviar, granular	−3 to −2	85–90	3 months
Caviar, pressed	−4 to −2	85–90	6 months

In refrigerated storage of iced fish a major aim is to conserve the ice, so that it is available for protection during subsequent transportation and handling. Opinions differ whether the temperature should be maintained slightly above 0°C (32°F) to keep the fish surface wet by slowly melting ice, or if the temperature should be reduced towards the freezing point for better keeping quality. It has even been advocated to store fish in a part-frozen condition at −2° to −4°C (+28.4° to +24.8°F) to extend the storage period ("superchilling", "Scarlatti method"). It is believed that this will give a quality improvement over conventional refrigeration in ice only at storage times approaching the limit of acceptability.

Cold storage of fish in melting ice and with simultaneous mechanical refrigeration involves a rather delicate problem of regulation. The room thermostat is obviously unable to decide whether refrigeration is supplied from the ice or by the mechanical unit. Refrigerated rooms for this purpose therefore require special arrangements for capacity regulation. This is a fact which often has not been sufficiently observed in practice, sometimes with rather unfortunate results.

Since bacteria is the dominating cause of spoilage in most cases, any treatment to hold back their development will improve the keeping quality. Much research has been done on irradiation pasteurization and bactericides, with some measure of success. Many problems have still to be solved, however, before these methods can be generally accepted in the trade.

It is possible to gain much better control of the quality deteriorating processes by lowering the temperature well under the freezing point. The growth of micro-organisms is completely arrested at temperatures below, say, −10°C (+14°F) and other biochemical, chemical and physical processes are responsible for the slow quality reduction, which still goes on. The rate of these processes is greatly reduced as the temperature is lowered. Fish products are very sensitive and require much lower temperatures than most frozen foods. Fig 11 gives an indication of maximum storage time to a given quality standard for lean and fatty

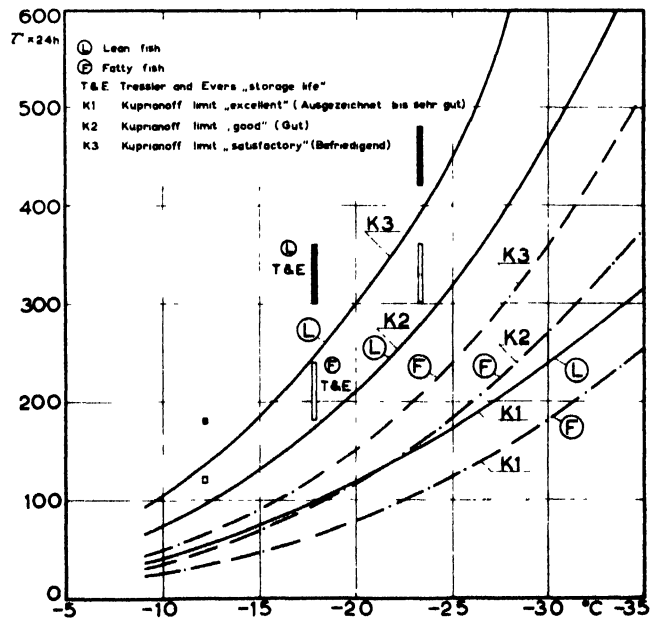


Fig 11. Keeping time to a certain quality reduction for lean (L) and fatty (F) fish according to Kuprianoff (1965) and Tressler (1957). Kuprianoff indicates limits for "excellent", "good" and "satisfactory" quality, while Tressler gives maximum storage time for three specific temperatures only

fish (Kuprianoff, 1965; Tressler and Evers, 1957). Temperature requirements have been constantly sharpened over the years, and today −30°C (−28°F) is a fairly common demand for long-term fish storage.

It should be noted that protective packaging, glazing or alginate coating can improve the storage life considerably, particularly in fatty fish. If the products are not thus protected, due precautions should be taken to design the storage rooms in such a way that the drying out is reduced to a minimum. This calls for a high relative humidity and small air movement. The ideal for unpackaged fish is a completely jacketed room.

Insulation

When inside and outside temperature conditions are known, the amount of insulation and refrigeration capacity can be decided on the basis of an economic optimum calculation. An old and very rough "rule of thumb" requires an insulation thickness in centimetres equal to half the temperature difference in degC. In reality the economic thickness depends on a number of variables. With the present extensive use of cheap mineral fibre materials and frequent demand of high relative humidity in the rooms, rather thicker insulations are applied now than was practical only a few years ago.

The insulation material should be chosen with due regard to its heat conductivity, workability, fire resistance, load bearing properties when required, durability and price, in addition to a number of other important properties. Table 2 gives some approximate data for a few of the more common materials. Slab cork was the dominant material up to some years ago, but is now rapidly moving out of the picture. Its main use is in floors and at other points where load bearing capacity is needed, but even here it is frequently replaced by foam plastic materials or foamglass. Walls and roofs are commonly insulated with mineral wool bats, combining easy erection with fire resistance and low price. Foamed-in-place plastics are gaining ground only slowly in spite of their technically attractive features, due to difficult application and high price. Foamglass may have advantages where it can be used simultaneously as an insulation and structural material.

All cold room insulation must be protected against infiltration of moisture, which will gradually reduce its

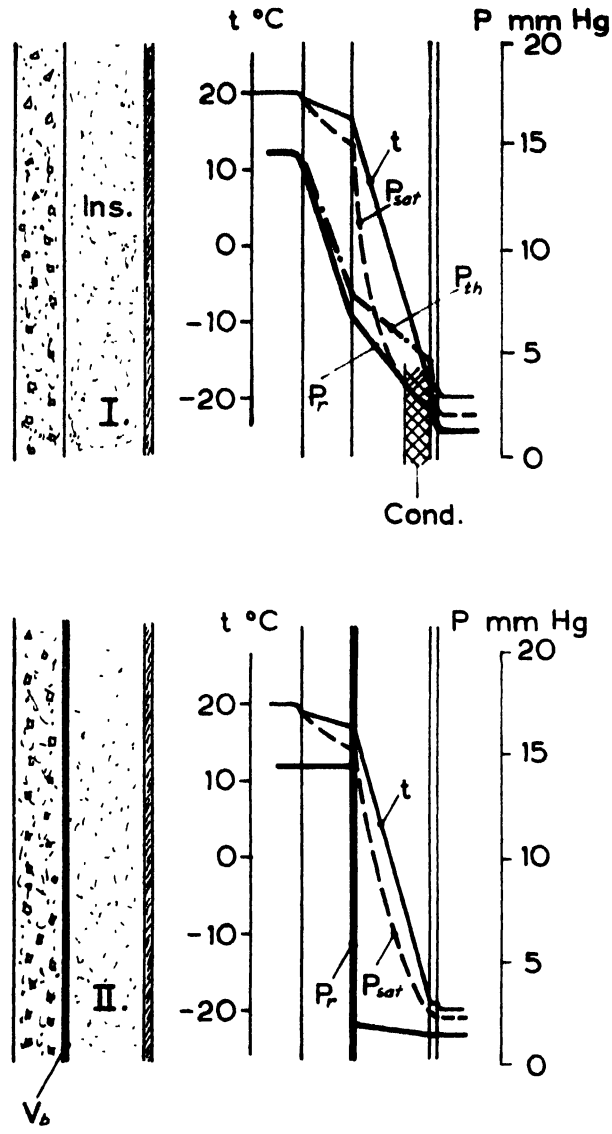


Fig 12. Functioning of the vapour barrier in an insulated wall. Wall I has no vapour barrier. The vapour pressure in the insulation reaches saturation and condensation occurs. Wall II has an efficient vapour barrier on the warm side. The vapour pressure in the insulation is reduced to a level where no condensation can take place. t, *temperature;* P_{sat}, *saturation vapour pressure corresponding to* t; P_{th}, *theoretical vapour pressure curve if no condensation occurs;* P_r, *real vapour pressure curve*

TABLE 2. IMPORTANT PROPERTIES OF SOME COMMON INSULATION MATERIALS

(The figures are approximate, intended only as a rough indication, and more accurate data for the particular make of material should be used for design purposes)

Insulation material	*Cork slabs*	*Rock-wool bats*	*Fibre-glass bats*	*Foam-glass*	*Exp. polystyrene*	*Exp. polyurethane*
Density, kg/m³	100–150	45–60	20–80	145	15–30	40
Heat conductivity, kcal/mh °C, 0°C	0.032	0.030	0.030	0.046	0.030	0.020
Resistance to entry of liquid water	Fair	None	None	Complete	Good	Good
Resistance factor for vapour diffusion, comp. to still air	20	1.5	1.5	∞	70	100
Fire safety	Poor	Good	Good	Excellent	Poor	Poor
Compression strength, kg/m²	5,000	None	None	30,000	2,000	3,000
Approximate price, Nkr/m³	350	50	50	600	200	600
Installation costs	Mod. high	Low	Low	Mod. high	Mod. high	High

efficiency and lead to ultimate destruction. With the rare exception of absolutely vapour-tight materials, a vapour barrier on the warm side is always necessary. Fig 12 illustrates how it functions. It can hardly be overstressed that extreme care in erecting the vapour barrier is probably the most important factor in securing a satisfactory period of useful life of any refrigerated structure, regardless of temperature level. The difficulties are particularly great in warm and humid countries.

Another important menace to effective insulation is convection, which may be set up by thermal differences in the structure or outside pressures (Lorentzen, 1965). Fibrous materials must be of sufficient density to provide the flow resistance required to avoid air circulation. Slab- or board-type insulations must be fitted in a way to avoid even small cracks or crevices, which can provide channelling for air movement. It is essential that the cladding is made in such a way that any air currents to or from the room are prevented.

Finishes

The internal floor finish must be suitable for mechanical handling equipment. Usually 8 to 10 cm granolithic reinforced concrete is adequate, provided it is laid expertly. Contraction must be allowed for by expansion joints, and the floors should be free to contract inwards from the walls without damaging insulation or finish. In some cases heavy wooden floors have been used in freezer stores with good results. They have the extra advantage that repairs are easily performed at low temperatures.

The internal finish of walls and ceiling insulation can be limited to what is required to keep it in place or improve its quality in strength, fire resistance and reduction of air movement inside it. For rigid insulations only a paint or plaster may be necessary.

In non-jacketed rooms battens are necessary to prevent stowage right up to the walls. A space of at least 20 cm should be left open to secure necessary air circulation to remove heat leaking in through the walls. A good solution is to arrange a curb at the wall and vertical battens of 2 in wood or other material at a distance depending on the dimensions of the products to be stacked. For a pallet operation it can be considered good practice to provide two battens per row, to give necessary support to the stacks (fig 7).

Doors

Refrigerator doors are a universal source of complaint. They have to comply with a number of requirements which are difficult to combine. Modern mechanical handling requires large door openings and has aggravated the situation. Much work is going on in different countries to improve designs. The trend is towards light construction in reinforced plastics with foamed-in-place insulation, in spite of the high cost.

In the smallest plants for manual handling the old style swinging door can still be used. They may be of the infitting or the overlap type, the latter design being generally preferred for low temperature rooms. Gasket heaters are common to avoid freeze up. The framing and hardware must be very strong and the door itself completely rigid to prevent warping or sagging with time. As soon as a door does not fit correctly, it deteriorates very rapidly. Leaky doors also impose a heavy load on the refrigeration and defrosting systems.

In larger plants for fork truck operation the doors become too large to be conveniently worked by hand. Sliding doors of different conception are becoming more and more common. When traffic is heavy it is good practice to provide double set doors for one-way passage to avoid obstruction and danger of collision. A number of systems for mechanical operation, electrical, hydraulic or pneumatic, are available. A new French design with inflatable gaskets and air operation of the sliding action has many attractive features (Ganzinotti, 1966). Operation can be actuated by manual switches or automatically by photo cells and timers. Protection by floor guards and bumpers is very important to avoid damage by careless truck operators.

The loss of refrigeration through open doors is tremendous, and the opening time should be reduced to a minimum. In practice this is a great problem, in particular during heavy traffic, and it is not uncommon to see doors left open for hours on end during filling or emptying a room. Under such conditions it is impossible to maintain correct temperatures, and many means to improve conditions have been suggested. The old solution of vestibules and double doors is rarely practised any more due to its obstruction of traffic and space requirement. Different types of air curtains have been introduced to reduce the exchange of air between the cold room and the outside. Although they improve the situation considerably when properly designed and adjusted, they provide no complete solution to the problem. The same may be said of the different types of flapper doors and rubber curtains available. A fully satisfactory access system for cold stores still has to be designed.

MACHINERY

There is nothing in particular to distinguish the refrigeration system for a fish plant from that of any other cold store or food processing establishment. Ammonia systems with reciprocating compressors are most common for plants above a certain size. Only the very largest installations sometimes use turbo-compressors with halocarbon refrigerants. As sea-water is frequently available for cooling, shell and tube condensers predominate.

Nearly all new installations are fully automatic, not only in order to save manpower, but also to get a more accurate and reliable operation.

CONCLUSION

The principles involved in design and operation of cold stores for fishery products do not differ much from those relating to other commodities. As a whole the technical solutions are much the same as universally accepted in the cold storage industry. In spite of this it must be said

that the nature of the product imposes some extra requirements:

(1) The wet nature of the raw material, whether in ice or not, gives extra moisture problems, which must be taken into consideration in designing the building and insulation.

(2) Sanitation problems are more difficult than in most industries.

(3) The seasonal fluctuation in the fishing industry necessitates great flexibility of the processing and storage plants to adjust to different products and capacity.

(4) The extreme perishability of the fresh fish gives special requirements to the speed of handling and accurate temperature control.

(5) Freezer storage temperatures for fish products should be considerably lower than necessary for most other foods.

(6) The traditionally rough treatment of equipment in the fishing industry demands a sturdy and simple design.

These factors should be taken into account in the design of any fish cold store.

References

GANZINOTTI, J V 1966 Les portes étanches à joint gonflable. *Revue gén. Froid*, pp. 903–912.

KUPRIANOFF, J 1965 Der Einfluss der Temperatur und Lagerdauer auf die Gefrierveränderungen von Lebensmitteln. *Kältetechnik*, pp. 102–107.

LORENTZEN, G 1962–63 The freezer chain—problems and possibilities. *Proc. Inst. Refrig.*, **59**, 109–154.

LORENTZEN, G 1965 The influence of convection in cold store insulation. *J. Refrig.*, **8** (2), 41–48.

MORPHEW, A E B and JONES, A J 1966 The design and construction of large cold stores. *J. Refrig.*, **9** (12), 307–313.

PERSSON, P O 1963 Some developments in cold storage and freezing during the last decade. *Kyltek. Tidskr.*, No. 4, pp. 77–83.

TRESSLER, D K and EVERS, C F 1957 The freezing preservation of foods. The AVI Publ. Co., Westport, Conn.

Trends in Building Design, especially Prefabricated Section Construction

by P. O. Persson

Trends in building design, especially prefabricated section construction

As a result of the trend towards faster and faster turnover of the goods stored in cold stores an adaptation of the general layout to modern handling technique becomes more and more important. Most new cold stores today are single-storey buildings for fork-lift truck operation and further mechanization is foreseen.

Prefabricated building elements were first used in the cold store industry as a substitute for brick or other structural material. The prefabricated elements were first made in special field factories.

A later development was factory-built elements, leading to reduced erection time and better economy. This was achieved by using standard modules, i.e. standardized columns, beams, purlins, wall and roof panels.

The wall insulation for this type of store is applied in various ways, but the roof insulation normally consists of prefabricated panels suspended from the roof.

Where local fire regulations permit, a less costly store can be made by using prefabricated steel structures. In this system, the external weather proofing consists of corrugated sheets of various kinds. The insulation is carried out with prefabricated insulation panels fitted to the inside of the structure.

A system using an internal steel structure with external insulation panels, which form a complete insulating envelope, can today be built faster than any other type of construction. The external surface serves as a vapour barrier, weather proofing and as a decorative surface. In the paper various types of panels are described.

The use of wall- or roof-mounted package refrigeration units together with prefabricated elements for the building makes very short erection times possible.

Evolution de la construction, et notamment emploi d'éléments préfabriqués

Etant donné l'accélération constante du mouvement des marchandises dans les entrepôts frigorifiques, il devient de plus en plus impératif d'adapter l'implantation de ceux-ci aux techniques modernes de manutention. Aujourd'hui, la plupart des nouveaux frigorifiques sont des bâtiments sans étage conçus pour permettre l'emploi de chariots élévateurs à fourche, et la mécanisation des opérations ne fera que s'accentuer.

On a commencé à employer les éléments préfabriqués pour la construction des entrepôts frigorifiques en remplacement des briques ou autres matériaux. Ces éléments ont d'abord été produits dans des ateliers spéciaux.

La mise au point ultérieure de la préfabrication en usine a permis de diminuer le temps de construction des entrepôts et de réaliser des économies. Ces progrès ont été permis par l'emploi de modules normalisés, notamment pour les piliers, les poutres, les pannes, les panneaux de murs et de toiture.

Pour les entrepôts frigorifiques construits selon cette technique, l'isolation des murs se fait de diverses manières, mais celle du toit est normalement assurée par des panneaux préfabriqués suspendus.

Lorsque les règlements locaux sur la protection contre l'incendie le permettent, l'emploi d'éléments structurels en acier préfabriques permet la construction d'entrepôts d'un prix de revient encore moindre. La protection contre les intempéries est assurée a l'extérieur par des plaques ondulées de divers types. Pour l'isolation, on emploie des panneaux préfabriqués appliqués contre les parois intérieures.

Un système consistant à assembler, autour d'une charpente en acier, des panneaux externes isolants, qui constituent une enveloppe complète, permet aujourd'hui de construire un entrepôt frigorifique plus rapidement que par n'importe quelle autre méthode. La surface extérieure sert d'écran d'étanchéité à la vapeur d'eau, de protection contre les intempéries, et joue en même temps un rôle décoratif. La communication décrit divers types de panneaux.

L'édification extrêmement rapide d'entrepôts est rendue possible par l'emploi de frigorigènes muraux ou plafonniers et d'éléments préfabriqués pour le bâtiment lui-même.

Tendencias en el diseño de la construcción, especialmente en la de secciones prefabricadas

Como resultado de la tendencia hacia el movimiento cada vez más rápido de salida de los géneros almacenados en los frigoríficos, adquiere a su vez mayor importancia la adaptación de la disposición general de éstos a las modernas técnicas de manipulación. Actual mente, casi todos los nuevos frigoríficos son locales de un solo piso para que puedan actuar los camiones de horquilla elevadora y se prevén otras clases de mecanización.

Los elementos estructurales prefabricados se emplearon primero en la industria de las cámaras frigoríficas en sustitución de os ladrillos o de otro material para tal fin. Los elementos prefabricados se construyeron primero en fábricas de campo especiales.

Otra medida posterior fué la construcción de los elementos en fábricas, lo que dió lugar a que se redujera el tiempo de la construcción y se hicieran economías. Esto se logró empleando módulos patrón, es decir, columnas, viguetas, jabalcones, paneles para tabiques y tejados de forma y medidas uniformes.

El aislamiento de las paredes para esta clase de almacenes se efectúa de varios modos, pero el aislamiento del tejado normalmente se hace con paneles prefabricados suspendidos desde el tejado.

Cuando lo permitan las ordenanzas municipales sobre incendios, se puede levantar un almacén más barato empleando estructuras prefabricadas de acero. Con este sistema, la protección contra el ambiente atmosférico exterior consiste en láminas acanaladas de varias clases. El aislamiento se realiza con paneles prefabricados que se adaptan al interior de la estructura.

Un sistema que emplee una estructura interna de hierro con paneles de aislamiento externo, que forman una envoltura completa de aislamiento, se puede construir en la actualidad con más rapidez que cualquier otra clase de construcción. La superficie externa sirve para evitar la absorción de humedad como protección impermeable y como superficie decorativa. En el estudio se describen distintos tipos de paneles.

El empleo de unidades compactas de refrigeración aplicables a las paredes o al techo, junto con elementos prefabricados para la edificación, hacen que sea posible la construcción en muy poco tiempo.

LOCATION AND LAYOUTS

EVEN if this paper is intended to deal with various construction problems experienced with the erection of cold stores, I cannot avoid starting by drawing your attention to the necessity of a careful study of the location and the layout of the cold store. The locality must be decided with regard to traffic coming in by road, by rail and by sea.

Another important factor is to have sufficient land available around the cold store to permit an easy and fast traffic flow and from the initial design stage the possibility of extensions should be considered in detail.

The necessity of having large yards is very often underestimated. Over the last few years there has been a continuous increase in the length of road vehicles, and in most countries this is likely to go on for several more years. This should be taken into consideration when the surroundings to cold stores are planned.

Everyone who stores frozen food in a cold store wants to have as high a turnover as possible, in order to reduce

the overall cost. The introduction of modern data technique helps to keep the inventory down, and to achieve faster movements of the products.

Until recently the use of standardized pallet loads and forklift trucks has been the best answer to the product-handling problems in cold stores, but today fully automatic cold stores are already in existence. These will, however, for the foreseeable future be very costly and can be considered only where the turnover is extremelv high.

Single-storey buildings with large rooms and a free height of 7 to 8 m have proven to be the most economical for forklift truck operation. Only if the land is extremely expensive and difficult to obtain, should a multi-storey building be considered. Such buildings should, if possible, be equipped with automatic pallet lifts in order to avoid the bottleneck associated with the ordinary type of lifts. Many modern forklift trucks allow the stacking of five pallets, 1.75 m each, giving a total stacking height of 8.75 m.

As part of a layout study, a store at ground level should be compared with a store at loading bank level; and although it is difficult to give a general recommendation, the decision should be based on the type of traffic to and from a store.

CONSTRUCTION

Floor construction

A cold store floor must always be protected against frost heave. For a small cold store some form of air circulation or an electric grid is the most practical solution, but for larger cold stores the best method is normally to use surplus heat from the refrigeration installation by the circulation of oil or glycol through a pipe system beneath the insulation.

Until recently this pipe grid has been installed in a heavy concrete subfloor, but later experience, especially in the United States, has shown that, provided the ground conditions are fairly good, it is possible to avoid these heavy subfloors. On well prepared and compressed ground the pipe grid is laid directly, and only protected by a thin layer of concrete. On top of this the vapour barrier and insulation are placed. To compensate for this lighter subfloor, the top floor is made somewhat heavier with more reinforcement. In this type of construction it is important that the joints are made in such a way as to allow contraction without weakening the top floor.

In table 1 various types of floor insulation material are listed. Nos. 1 to 3 are in the same price range, whilst no. 4 is more expensive. It should be remembered, however, that foamglass can be used without a vapour barrier, and also that this material can stand considerably higher loads than the other materials mentioned.

TABLE 1. COMPARISON OF "EUROPEAN AVERAGE" COSTS FOR FLOOR INSULATION MATERIAL

Material	*"Practical" λ-value kcal/mh °C*	*Cost comparison for equal insulation values*
Cork, expanded	0.035	100
Styrofoam	0.035	95–100
Polyurethane density 35 to 40 kg/m³	0.025	100–110
Foamglass	0.045	200

Building construction

In the early days conventional bricks or concrete were the principal building materials for cold storages. The first step towards prefabrication was made when prefabricated sections were substituted for the conventional brick or concrete walls. In Sweden the first cold store building with walls consisting of horizontal concrete elements, 0.3×3 m between vertical concrete columns, was constructed in 1951.

During the following years methods using larger and larger prefabricated slabs were developed. The largest wall elements ever used by our company were 1.5 m in width and 10 m high. For roof elements, however, we went even further and made roof slabs in concrete, 1.5 m and 18 m long.

These elements were first manufactured in field factories but today prefabricated concrete elements of standardized fabrication can be purchased from permanent factories. We now believe that a prefabricated concrete structure for a cold store should be built using wall elements approximately 1.5×6 m, laid horizontally between concrete columns.

For the roof construction, different standardized methods have been developed in various countries, and a general recommendation is difficult to give.

Insulation of walls and roof

The prefabricated shells were initially insulated in accordance with the different types of insulating material used. Slabs of cork or polystyrene were fixed to the wall surface with hot bitumen. When fibreglass was used large blankets of this material were suspended on the wall in two layers, with the vapour barrier fixed to the walls before the insulation was applied.

When cork or polystyrene was used for roof insulation it was necessary to build a false ceiling, normally of timber. The vapour barrier was then set to the underside of the false ceiling and the cork or the polystyrene was fastened underneath it. When fibreglass was used, panels were normally factory made and suspended from the roof beams. The vapour barrier was then applied to the top of the panels.

Later on the small polystyrene slabs used on the walls were substituted with very large slabs in order to speed up the erection of the wall insulation.

STANDARDIZATION

Standardization—prefabrication

From what I have said so far a clear tendency can be seen towards more and more standardization and prefabrication. Three years ago an investigation was made in the United States by Mr. A. W. Ruff as to the number of cold stores built using prefabricated insulation panel construction, in comparison with conventional methods. Mr. Ruff's investigation covered the period from 1957 to 1963, and 100 installations built within this period. As will be seen from fig 1 there is a clear trend towards more and more panel constructions. The trend still continues,

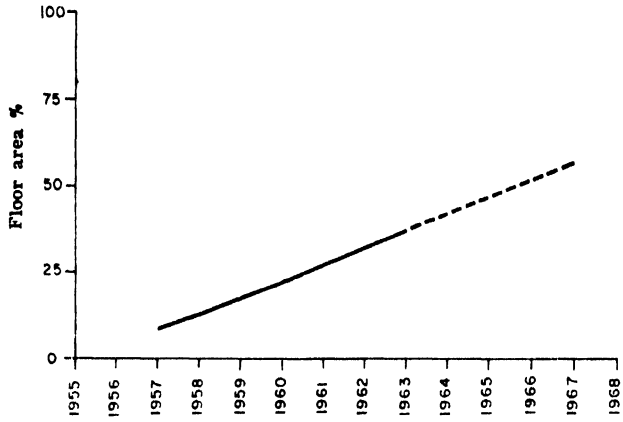


Fig 1. Panel-built cold stores share of the market in the United States. Based on a study of 100 cold stores built 1957–63

and today well over 50 per cent of all newly-erected cold stores in the United States are likely to be of insulated panel constructions.

Table 2 shows a cost comparison between different methods of cold store construction. The comparison is made for cold stores with an area of 3,000 m² (32,000 ft²) and shows the relative cost for two types of construction:

(1) Steel structure with polyurethane panels for walls and roof.

(2) Complete concrete building with internal insulation.

TABLE 2. RELATIVE COST FOR TWO TYPES OF COLD STORES

Floor area 3,000 m² on platform height
Inside clear height 7 m
Costs for cold storage building, doors and insulation only are included

Construction parts	*Steelframe wall-panels, roofpanels*	*Concrete building internal insulation*
Foundations	6	7
Frame	21	27
Floor	20	20
Roof	25	36
Walls	26	31
Doors	2	2
Total cost	100	123

The basic data for this comparison was collected from the United States and Europe, and I have tried to use average figures. I am anxious to stress, however, that local conditions from country to country obviously have a great influence on the cost for various types of construction. The intention with my summation is only to try to show a general tendency. This comparison shows clearly that a panel construction is less expensive than a concrete building. The cost difference between a panel construction using a concrete structure or a steel structure is not so pronounced, but in most cases the steel structure gives a lower cost.

Different types of panels

Table 3 illustrates the difference in cost between insulating materials for walls and roofs. Here there is a much higher variation than for floor insulation as shown in table 1.

If you made your decision regarding the type of material using this table, you would definitely select mineral wool or fibreglass. But unfortunately it is not so easy. When using fibrous material in a panel construction it is necessary to spend some money on framework and to use fibreboard or plywood externally and internally in order to get a rigid panel. Other materials like polyurethane can be foamed between outer and inner skins of flat or corrugated metal without any framework at all.

TABLE 3. COMPARISON OF "EUROPEAN AVERAGE" COSTS FOR WALL AND ROOF INSULATION MATERIAL

Material	*"Practical" λ-value kcal/mh °C*	*Cost comparison for equal insulation values*
Fibreglass density 24 kg/m³	0.035	50
Fibreglass density 40 kg/m³	0.035	85
Polystyrene density 20 kg/m³	0.035	100
Styrofoam	0.035	190
Polyurethane density 30–35 kg/m³	0.025	190
Foamglass	0.045	360

This simpler panel construction compensates for the higher material cost, and today there are several manufacturers of panels using fibreglass as well as many who use plastic materials in their panels.

The types of panels normally used today are:

(1) Fibreglass panels with wooden frames and having external and internal skins of plywood, normally with an additional outside skin of aluminium as vapour barrier and finish.

(2) Polystyrene panels with or without frames but normally with external and internal skins of plywood in the same way as for fibreglass.

(3) Polyurethane panels with polyurethane foamed between two skins of corrugated or flat metal, aluminium or galvanized steel.

The different types of panels are all delivered from the factory complete with internal and external skins. After erection the panels are bolted or drawn together with cam locks, the joints tightened with packing strips or with polyurethane "foamed *in situ*".

The external vapour barrier is sealed with thiocol or non-hardening sealing compound covered with a metal strip.

Some manufacturers are using a system for joining one panel to another whereby the sheet metal on one panel is folded over the pre-bent edges of the adjacent panel.

These panels are normally erected on the outside of the structure as also is the roof insulation, which means that the thermal insulation and the vapour barrier form a complete unbroken envelope.

The use of panels for wall insulation is sometimes combined with a roof insulation built on site. The roof insulation material is then laid on top of corrugated steel sheets or concrete panels, depending on the degree of fire protection required.

Irrespective of whether panels are used on the roof or the roof insulation is built on site, it has to be finished with a weather protection to the highest possible standard.

The only exception to this is where a type of panel is used with the upper side consisting of sheet metal which is acceptable as roofing material. The correct jointing of such panels is obviously very important.

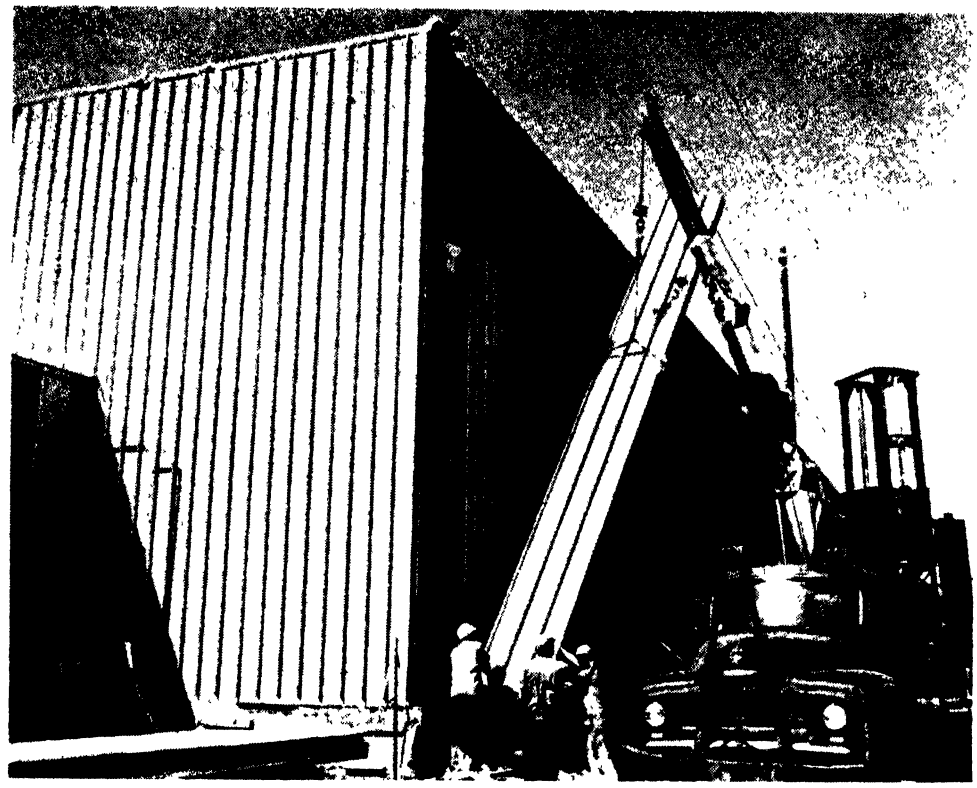


Fig 2. Erection of a prefabricated panel consisting of corrugated aluminium with a polyurethane core. Dimensions are 1.2×8.5 m (4×28 ft)

On all panel-built constructions as well as on those where the insulation is applied to an existing building, the joints between floor and walls, between walls in corners, and between walls and roofs, should be carefully engineered. Most failures in the insulation occur at these critical points.

A very good method when sealing these corners is to use polyurethane "foamed *in situ*".

Fire regulations

Unfortunately a decision cannot be made only from the cost point of view. The cold store must be constructed in accordance with the local fire regulations and the "fire class" of the building has also a great influence on the insurance costs for the building and the stored merchandise.

If a fire-proof cold store is required this is in most cases best achieved by using a concrete building. It is, however, also possible to use insulated panels and to add a masonry wall.

Refrigeration systems

Even if this paper deals mainly with the building and insulation work in connection with cold storage, I feel that it is appropriate to point out that today there is also a clear trend towards standardization as far as refrigeration systems are concerned. As a parallel to the development of more and more prefabricated elements for cold store design, there is development of standardized package units for refrigeration of cold storages. So far, however, these units are limited to certain dimensions having regard to size limitations for easy transport and easy erection work. For larger cold stores, this problem has partly been overcome by installing a number of units. Around-the-clock service in cold store engine rooms is not necessary nowadays.

COSTS

Investment cost—maintenance cost and fire risk

The replacement of conventional building techniques by prefabricated concrete construction was the first step towards reduced erection time and cost, whilst still maintaining quality.

This was followed by the prefabrication of insulation elements which, when used with prefabricated concrete building methods, produced a further step in the same direction.

The use of complete panel construction for walls and roof has further reduced erection time and costs, but from the fire resistance, and in many cases the maintenance, points of view this system does not equal a well-insulated concrete building.

It is to the cold store designer's credit that erection costs have not risen, and in many cases have been lowered, during the past decade, in spite of the fact that most prices have gone up. Let us hope that this development work will continue to the benefit of the cold store owners and users.

Finally, however, a word of warning—let us not go so far in design simplification that our operation and maintenance costs rise too far, and let us also not neglect the fire risk.

La protection des isolations contre la pénétration de la vapeur d'eau

par P. Clément

La protection des isolations contre la pénétration de la vapeur d'eau

L'auteur rappelle la manière dont la vapeur d'eau peut pénétrer à travers l'isolation d'une chambre frigorifique de conservation, ce qui a pour effet de diminuer le pouvoir isolant et même de causer, par congélation de l'eau à l'intérieur du matériau isolant, la rupture de celui-ci. Il décrit les moyens utilisés pour protéger les isolations: "barrières anti-vapeur", comme les produits bitumineux ou les complexes polycouches (feuilles métalliques solidaires de bitume ou de plastique), ainsi que leurs modalités d'application aux sols, murs et plafonds des chambres froides. L'auteur étudie ensuite les isolants étanches à la vapeur d'eau, puis l'emploi de panneaux "sandwich" préfabriqués à parements métalliques ou en stratifié.

Protection of cold store insulation against moisture penetration

The paper discusses the mechanism by which water vapour may enter the insulation of a cold store and lead to decreases in insulating value, freezing and even breakdown of the insulating material. The use of vapour barriers such as bituminous coatings, metal foils associated with bitumen and plastic products and their application to floors, walls and ceilings of cold stores is described. The author also discusses the use of moisture-proof insulating material and cold stores constructed of prefabricated insulating panels with metallic or plastic coatings.

La protección del material aislante contra la penetración del vapor de agua

Se examina la manera en que el vapor de agua puede penetrar en las partes aislantes de un frigorífico y dar lugar a pérdidas en la capacidad de aislamiento, a la congelación e incluso a la rotura del material aislante. Se describe el empleo de defensas contra la penetración de la humedad tales como revestimientos bituminosos, hojas de metal acompañadas de productos bituminados y plásticos, y su aplicación a los pavimentos, paredes y techos de los frigoríficos. El autor examina también el uso de material aislante a prueba de humedad y frigoríficos construidos con paneles aislantes prefabricados con revestimientos metálicos o plásticos.

Pénétration de la vapeur d'eau

POURQUOI faut-il protéger les isolations contre la *pénétration de la vapeur d'eau*?

Le diagramme (fig 1) permet de répondre instantanément à cette question: il comporte deux courbes qui se superposent presque exactement et représentent, en fonction de la température:

la première, la tension maxima de la vapeur d'eau dans l'air;

la deuxième, le poids maximum de vapeur d'eau contenue dans 1 m^3 (35,3 ft^3) d'air.

On voit qu'à −30°C (−22°F) la tension et le poids de vapeur d'eau contenue dans l'air sont pratiquement nuls, alors qu'à 30°C (94°F), la tension de la vapeur d'eau est de 31,54 mmHg (1,24 inHg) alors que le poids de la vapeur contenue dans 1 m^3 d'air est de 30 g (1,06 oz).

Il n'est pas rare que l'air au contact des deux faces d'une isolation de chambre frigorifique de conservation soit à des températures de 30°C à l'extérieur et −30°C à l'intérieur.

Par conséquent, l'air extérieur contiendra (à saturation) 30 g de vapeur d'eau par m^3 (1,3 gr/ft^3) sous une tension de 31,54 mmHg alors que l'air intérieur sera pratiquement sec.

Il est bien évident que si l'on ne prend aucune précaution, la vapeur d'eau sous tension de 31,54 mmHg migrera à travers l'isolation vers l'intérieur de la chambre qui contient de l'air pratiquement sec.

Inconvénients de la vapeur d'eau

Si ce phénomène est d'une évidence indiscutable, on peut se demander pourquoi il présente des inconvénients et pourquoi il faut empêcher qu'il se produise.

La réponse est également très simple: si un matériau est isolant c'est parce qu'il contient une multitude de petites cavités microscopiques contenant de l'air sec et que l'air sec est un excellent isolant: son coefficient de conductibilité λ étant inférieur à 0,02 kcal/m h °C (0,16 Btu/ft^2 h °F/in).

Si l'air au lieu d'être sec contient de la vapeur d'eau, son pouvoir isolant diminue car la vapeur d'eau a un coefficient de conductibilité égal à 0,142, soit sept fois celui de l'air sec.

Si cette vapeur d'eau se condense à l'intérieur de l'isolation, le pouvoir isolant est encore réduit car le coefficient de conductibilité de l'eau est 25 fois plus élevé que celui de l'air sec.

Si l'on admet que le gradiant de température est linéaire dans l'épaisseur de l'isolation, on constate que dans une isolation dont les faces sont respectivement à 30°C et −30°C, une moitié de l'isolant est à une température supérieure à 0°C (32°F), tandis que la deuxième moitié est à une température inférieure à 0°C (32°F). Il en résulte que l'eau contenue dans l'isolation se congèle.

Le pouvoir isolant est encore réduit puisque le coefficient de conductibilité de la glace est égal à 2 (16), soit 100 fois plus élevé que celui de l'air sec.

Par ailleurs, la congélation de l'eau dans l'isolation provoque des désordres graves: gonflement, ruptures, désagrégation, etc.

Par conséquent, ce rapide rappel permet de démontrer qu'il est indispensable de protéger l'isolation d'une chambre froide contre la pénétration de la vapeur d'eau.

Cette protection est d'autant plus nécessaire que l'air extérieur est plus chaud et plus humide et que la température intérieure est plus basse.

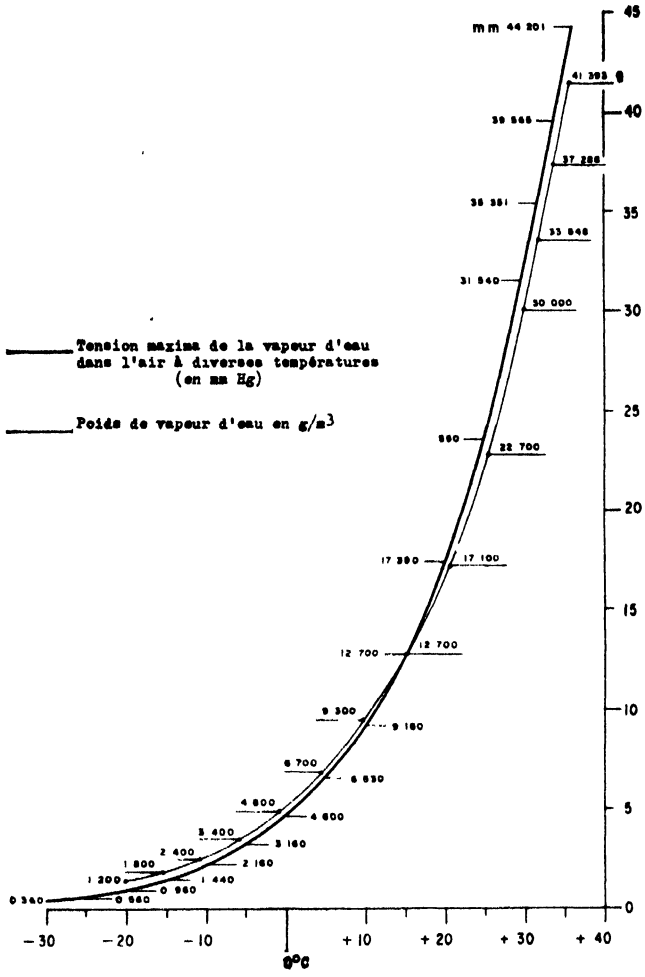


Fig 1. Tension maxima et poids de vapeur d'eau dans l'air, à diverses températures

MOYENS DE PROTEGER LES ISOLATIONS

Nous allons étudier maintenant les moyens utilisés pour protéger les isolations contre la pénétration de la vapeur d'eau.

On distingue deux procédés bien différents:

le premier (qui est le plus répandu) consiste à réaliser une enveloppe extérieure étanche à la vapeur d'eau "une barrière anti-vapeur", qui protège les isolants qui, pour la plupart sont plus ou moins poreux ou perméables à la vapeur d'eau;

le deuxième procédé consiste (et c'est l'idéal), à utiliser des isolants étanches ou imperméables à la vapeur d'eau. Dans ce cas, il est inutile de réaliser une barrière anti-vapeur.

Barrière anti-vapeur

Ces barrières peuvent être réalisées soit par application d'une couche de produits bitumeux pâteux, soit par collage de complexes constitués de feuilles d'aluminium et de produits bitumeux ou plastiques, soit encore par combinaison des deux procédés.

Produits bitumeux. Les produits bitumeux sont généralement utilisés sous forme d'émulsions aqueuses qui sont appliquées sur les murs préalablement recouverts d'un enduit d'égalisation au mortier de ciment exempt de chaux. L'application peut être faite à la brosse, au pistolet ou à la truelle à raison de 3 ou 4 kg/m² (0,6 ou 0,8 lb/ft²).

Le Flintkote HPC1 de la Shell a une perméabilité de 2 à 3 g de vapeur d'eau par 24 h et par m² (2,9 à 4,3 gr/ft² 24 h) pour une ambiance de 38°C (99.50°F) et 90 pour cent d'humidité (NF.X.41001). Le Flintkote "Vapour Barrier—Type T" qui est une émulsion de bitume et de latex a une perméabilité encore plus faible puisque la quantité de vapeur d'eau qui passe dans les conditions précédentes est si faible qu'elle n'est pas mesurable.

On fait appel aussi à des solutions de bitumes fibrées ou non (mastics Foster) dont la perméabilité est seulement de 0,4 g/m² 24 h (0,6 gr/ft² 24 h) sous 45 mmHg (1,8 inHg). Sur les sols, on préfère généralement utiliser le brai de pétrole qui est versé bouillant sur la forme en béton. Pour être efficace la couche de brai doit avoir une épaisseur de 10 mm (0,4 in).

Complexes polycouches. Les complexes polycouches comportent toujours une feuille d'aluminium qui peut être accolée à différents matériaux qui les rendent thermo-sondables. La feuille d'aluminium de 0,08 ou 0,10 mm (0,003 ou 0,004 in) d'épaisseur peut être collée sur une chape de bitume laminé armée ou non d'une toile (Paxalumin, Ruberalu). La feuille d'aluminium peut aussi être collée entre deux laminés de bitume, elle est ainsi protégée contre les chocs (Rubermétal).

Ces différents complexes ne doivent pas être collés, ils sont fixés par ramollissement à la chaleur de la sous-face de bitume et de l'imprégnation ou de la colle de brai, préalablement mise en place sur les murs.

La feuille d'aluminium peut également être solidaire d'autres matériaux que le bitume et notamment la toile ou le papier Kraft d'un côté et le polyéthylène de l'autre (Valluthène).

Ces complexes ont une perméabilité à la vapeur d'eau de 2,5 g/m² 24 h (5×10^{-4} lb/ft² 24 h) à 40°C (116°F). Ils sont thermo-sondables à la pince ou à la presse.

Ces différents complexes à base d'aluminium permettent de réaliser des barrières anti-vapeur sur les murs, au sol, mais principalement sur les plafonds suspendus. Dans ce cas particulier, la pose doit être réalisée avec beaucoup de soin notamment en ce qui concerne les soudures des lés entre eux.

Un des complexes les plus intéressants paraît être le Vapostop de l'Australian Sisalkraft Pty., Ltd. Ce complexe laminé comporte trois feuilles d'aluminium liées ensemble par du polyéthylène renforcé par deux couches de papier Kraft de forte densité avec une armature quadrillée de fibre de verre enrobée dans un adhésif spécial résistant au feu.

La perméabilité à la vapeur d'eau est inférieure à 0,01 Perm*, soit environ 6 mg/m² h pour une différence de température d'environ 60°C (108°F) entre les deux faces.

Le Vapostop peut être utilisé, sur les murs et le plafond mais aussi sur le sol. Dans ce cas, il convient de l'isoler du béton par une feuille de polyéthylène de 0,006 in (0,15 mm) d'épaisseur.

Quelle que soit la marque et la nature du matériau utilisé, il convient de prévoir des recouvrements de 10 à

* Un perm = 1 "grain" de vapeur d'eau par ft² par h sous une différence de 1 inHg de pression partielle de vapeur d'eau entre les deux faces (0,7 g/m²h sous 25,4 mmHg).

15 cm (4 à 6 in) de chaque côté des feuilles. L'assemblage doit être réalisé par soudure ou au moyen de rubans adhésifs appropriés.

Les barrières anti-vapeur doivent être absolument continues, notamment dans les angles avec un jeu suffisant pour permettre les contractions et les dilatations dues aux mouvements provoqués par les variations de température, d'humidité ou les tassements de bâtiment.

Des précautions particulières doivent être prises autour des portes où les feuilles sont repliées pour recouvrir la tranche de l'isolation, et aussi autour des tuyauteries qui traversent l'isolation. Il est bon de constituer, autour des tuyauteries un cadre sur lequel est collé le complexe, le cadre étant rempli par coulage d'un matériau isolant étanche.

Combinaison des deux procédés. On peut aussi utiliser pour la réalisation de la barrière anti-vapeur, une combinaison des deux procédés: produits bitumeux et complexes en feuilles comme nous l'avons vu récemment en Suède. Sur les murs, recouverts d'un enduit de ciment, application à la truelle d'une couche de produit bitumeux.

Sur cette couche, on applique un complexe aluminium bitume qui est déroulé contre les murs, la feuille d'aluminium étant du côté du mur, et chauffé fortement à la lampe au fur et à mesure, du déroulement, de sorte que l'on obtient une adhérence parfaite. Les feuilles de 1 m (3,3 ft) de largeur sont placées à une distance de 80 cm (2,6 ft), on colle ensuite une autre feuille par le même procédé, de sorte que le recouvrement est de 10 cm (4 in).

Enfin, on recouvre le complexe aluminium-bitume par une couche de brai.

On réalise donc ainsi une barrière anti-vapeur d'une remarquable étanchéité.

Perméabilité de la face interne

Il est important de préciser que si l'isolation doit être rigoureusement imperméable à la vapeur d'eau sur la face chaude, elle doit être aussi perméable que possible sur la face froide de façon à ce que l'humidité qui aurait pu pénétrer accidentellement dans l'isolation puisse en sortir et aller se condenser sur la batterie froide. Ceci est extrêmement important et il faut veiller à ce que les enduits, peintures ou autres revêtements que l'on applique sur les isolations soient perméables à la vapeur d'eau.

Nous citerons à ce propos l'exemple d'une chambre froide dans laquelle, par suite d'une erreur de l'entrepreneur, l'isolation avait été recouverte sur une paroi intérieure, d'une barrière anti-vapeur identique à celle qui avait été réalisée à l'extérieur. Par suite d'un accident, la barrière extérieure a été détériorée. Nous avons constaté que la vapeur d'eau avait pu s'échapper partout de l'isolation, sauf sur la paroi étanche où il s'était formé, en quelques mois, contre l'étanchéité interne, une couche de plusieurs millimètres de glace.

MATERIAUX ISOLANTS ETANCHES

Le meilleur moyen d'éviter la pénétration de la vapeur d'eau dans l'isolant est évidemment d'utiliser des isolants étanches et notamment des isolants à structure cellulaire fermée. Mais encore faut-il que le support des cellules soit étanche: le béton cellulaire par exemple est remarquablement poreux car le béton est poreux.

Par contre, des matériaux comme: le caoutchouc mousse, l'ébonite mousse, la mousse de chlorure de polyvinyle, la mousse de verre ou Foamglass sont remarquablement étanches car le caoutchouc, l'ébonite, le chlorure de polyvinyle, le verre sont étanches.

Les isolations réalisées avec ces matériaux sont donc étanches à condition que les joints entre plaques soient parfaitement étanches.

Il existe d'autres matériaux à structure cellulaire fermée qui sont souvent considérés comme étanches à la vapeur d'eau car ils sont plus étanches que le liège, la laine de verre ou la laine de roche, mais qui, en fait, ne le sont pas complètement. C'est le cas des mousses de polystyrène, et même des mousses de polyuréthane.

Il existe deux catégories de polystyrène: le polystyrène expansé et le polystyrène extrudé ou Styrofoam. Le deuxième est beaucoup plus étanche que le premier mais il ne l'est pas complètement et doit toujours être protégé par une barrière anti-vapeur.

En effet, le Styrofoam de 30 kg/m^3 (1,9 lb/ft^3) de densité a une perméabilité de 1,6 g cm/24 h m^2 44 mmHg, alors que le polystyrène de 20 kg/m^3 (1,2 lb/ft^3) a une perméabilité de huit, environ cinq fois plus.

Le fabricant cite le résultat de calculs qui ont été faits pour des isolations de différentes épaisseurs à différentes températures. Il en résulte que la quantité d'eau restant dans une isolation de 20 cm (8 in) d'épaisseur avec des températures de 15°C (59°F) à l'extérieur et −22°C (−7,5°F) à l'intérieur est de l'ordre de 2 pour cent du volume de l'isolation après 20 ans de fonctionnement ce qui représente 4 kg d'eau par m^2 (0,8 lb/ft^2) ou, pour une chambre de 1 000 m^2 (10 700 ft^2), une quantité totale de plus de 10 000 kg (10 t), ce qui est considérable.

Encore faut-il préciser que ces calculs ont été établis en tenant compte du fait que l'isolation n'est revêtue à l'intérieur d'aucun enduit étanche.

Il en résulte que la vapeur d'eau qui se trouve dans l'isolation peut en sortir, au moins en partie, puisqu'elle est attirée vers la batterie froide.

Il est certain que si ces expérimentations avaient été faites avec une barrière anti-vapeur interne, on aurait mesuré, à l'intérieur de l'isolation, une quantité encore plus importante de vapeur d'eau.

On peut donc conclure de ce qui précède que même les isolants dits "étanches" doivent être recouverts extérieurement d'une barrière anti-vapeur car même s'ils étaient parfaitement étanches, il peut se produire des retraits, des ruptures de joints par lesquels il peut pénétrer de la vapeur d'eau.

C'est ainsi que le fabricant du Foamglass recommande bien que les joints entre plaques, soient réalisés au moyen d'un mastic à base de bitume et de résines, de recouvrir la face extérieure des isolations d'une émulsion de bitume. Sur les réservoirs il demande l'application d'un enduit de bitume armé d'un tissu de verre.

PANNEAUX PREFABRIQUES

Il existe un autre moyen de rendre imperméables à la vapeur d'eau des isolants qui ne le sont pas ou pas complètement; c'est de les utiliser en panneaux préfabriqués, suivant la technique du sandwich.

On sait qu'un panneau sandwich est constitué de trois éléments: une âme épaisse en matériau isolant et deux revêtements minces.

Chacun des éléments n'a que sa résistance propre mais la combinaison des trois éléments donne à l'ensemble une résistance considérable qui est obtenue par la parfaite cohésion des trois éléments. Les revêtements peuvent

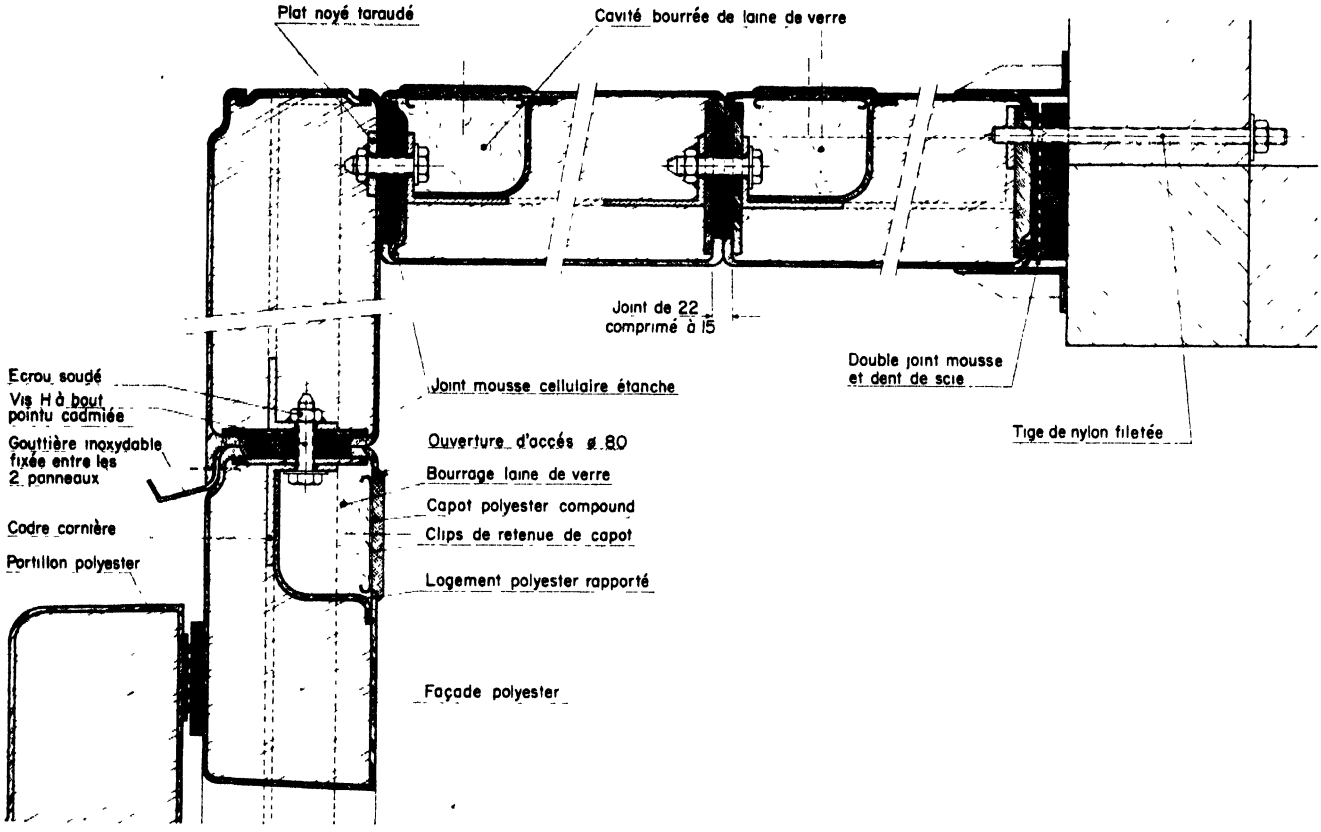


Fig 2. Détail d'assemblage des panneaux

être en tôle galvanisée, duralumin, en fibrociment. en contreplaqué ou encore en stratifié verre polyester.

Dans tous les cas les revêtements sont parfaitement étanches.

Plusieurs techniques sont utilisées pour la construction des panneaux sandwich:

collage des revêtements sur l'âme;

polymérisation directe du stratifié de polyester sur l'âme;

fabrication *in situ* de l'âme isolante entre des revêtements en plaques;

fabrication *in situ* des revêtements stratifiés et de l'âme isolante.

Nous n'entrerons pas dans le détail de la construction des panneaux sandwich. Nous insisterons seulement sur le fait que le dernier des procédés précédents est le meilleur car il permet d'obtenir d'une part, une parfaite cohésion entre les trois constituants et, d'autre part, une étanchéité totale du panneau.

Les matériaux isolants utilisés pour fabriquer les panneaux sandwich sont le polystyrène, le chlorure de polyvinyle expansé (Klégecel) et surtout la mousse de polyuréthane, cette dernière ayant seule le grand avantage de pouvoir être expansée "*in situ*" à l'intérieur des revêtements.

Les panneaux ainsi fabriqués sont assemblés sur place et ne nécessitent aucune charpente métallique pour les chambres de petites dimensions.

Pour les grandes chambres, il est indispensable de prévoir une charpente métallique qui peut être soit extérieure et dans ce cas les panneaux du plafond sont suspendus à la charpente de la toiture, soit intérieure, de façon à rapporter les panneaux du plafond.

On s'efforce de rendre cette charpente intérieure utile et notamment pour constituer des étagères de stockage.

Bien entendu, le mode d'assemblage des panneaux entre eux doit être étudié avec soin de façon à réaliser une rigidité et une étanchéité parfaites. Le système représenté sur la fig 2 donne satisfaction à ce double point de vue.

DISCUSSION

Foley (Canada): I would like to have seen a slightly longer treatment of jacketed rooms, and perhaps further departure from the conventional loading docks or railway, or road transportation of fish. Dr. E. J. Rosenberg in Commission V of the International Institute of Refrigeration presented a paper dealing with cold storage design and showed a slide of the refrigerated storage of the future, in which highway trailers were loading within the room. It was greeted with some astonishment. However, I feel that the design of such rooms cannot come quickly enough.

Persson's paper "Trends in building design, especially prefabricated section construction" is certainly worth the

attention of those owners and engineers interested in refrigerated storage design and construction. He points out that certain economies can be realized over the older conventional type of buildings. I would suggest, however, a few words of caution. The economies shown are probably valid in areas of high-cost labour, in others the savings may disappear. Also, there is the suggestion in this paper that, with automatic self-contained or packaged refrigeration units, around the clock service is not necessary in cold storage engine rooms. In many countries labour laws and union regulations and regulations under pressure vessel acts may preclude unattended operation except in very small refrigerated storages.

Lorentzen (Norway): Regarding jacketed rooms, I think it is right to say that the considerable experience gained during the 20 years the system has been in use, demonstrates very well the advantages in reduced drying out of unprotected produce. The construction costs are not very much higher than for a conventional cold store, and are at least partly offset by advantages in design of the air cooler system and, particularly, advantages in maintaining a completely dry insulation. There is a practical difficulty in that the jacket system is not well adapted to the cooling down of warmer products to storage temperature, which may be a problem in practice. Also, it is clear that in a larger store the drying capacity is relatively less than in a smaller room. This may be the explanation why jacketing is not so commonly used in large freezer stores as might be expected.

Merritt (U.K.): I am not able to say a great deal about jacketed cold stores. One can see, however, that generally speaking, the jacketed system will be less attractive as the cold store becomes bigger, as the ratio of surface to volume decreases. MacCallum of Canada has examined the question of jacketed fishrooms in fishing research and favours the normal method of insulation, I believe. There is little commercial interest in the jacketed cold store. On the latter point, I would make a plea for more information. Data on the amount and pattern of dehydration in stores of various designs would be of interest. There are a number of variations, including type of cooler, gravity circulation of air or forced circulation, jacketed or ordinary insulation and wrappers of various kinds or no wrappers.

Slavin (U.S.A.): I think that two points have been made here. One is that the jacketed store is perhaps very good and the other is that the jacketed store is not being used. It has been suggested that perhaps we should have some performance data.

Persson (Sweden): About a year ago I visited a cold store with many rooms, cooled by a jacketed system. I was surprised to see that in every one of these rooms they had installed ordinary air coolers with fans. The reason for this was that they could not hold the temperatures in the rooms with only the jacketed system because they could not avoid taking in products with a temperature considerably higher than the storage temperature. Therefore they needed more refrigeration capacity than foreseen when the jacketed system was installed. I believe this is one of the reasons why jacketed stores have not been more commonly used.

Lorentzen (Norway): A lot could be said with reference to the problem of drying capacity in cold stores. It is, in principle, a fairly straightforward problem of heat and mass transfer. A proper analysis will show that the heat introduction to the room through the insulation, by warm products, etc., is the most important single factor involved. Radiation heat exchange in the room is important, and improvement is possible simply by suitable selection of wall and ceiling surface materials.

Banks (U.K.): I wish to make a point regarding jacket cold stores that might be of some economic importance. Because the heat leak is taken up before it reaches the cold store it is possible to balance the refrigeration cost with insulation cost to obtain the most economic total cost without affecting in any way the drying effect of the cold store.

Roach (Canada): On the west coast of Canada there are many large cold storage plants used for storing fish. Most of this fish is salmon and halibut stored in the round after coating with an ice glaze. Loss of the glaze through desiccation is a major problem during prolonged storage of large quantities of fish since periodic reglazing is a most difficult procedure. This problem has been overcome in the two major plants built in British Columbia in recent years. These use jacketed cold storage rooms exclusively. The newest installation consists of a single large jacketed room which is probably the largest room of this type in existence. In British Columbia, introduction of this type of storage room has proven very successful.

Heen (Norway): The need for lower temperature can never be repeated too often. Lorentzen made a very important observation to the effect that it is not as expensive to lower the storage temperature in a large modern storage plant as many people believe. Of course, the decision as to storage temperatures for frozen white fish is a compromise between the investment and operating costs and what you achieve by this investment. I have the feeling that among industrialists as well as refrigeration engineers, the effect of temperature is still not well understood. The compromise is not static. When 25 years ago a level of 20°C (−4°F) was considered a reasonable compromise, this was no expression that it was the desirable storage temperature. With improvement in insulation and refrigeration equipment, it is comparatively cheaper today to operate at storage temperatures 10 degC (18 degF) lower than the compromise of 25 years ago. And I will add that the salient point as far as white fish is concerned, is that temperature is just as important for short-term storage as for long storage. The peculiarity is that the rate of changes at a given temperature level proceed with greater rapidity during the initial stages of storage. A lower storage temperature will therefore lift the general level of quality of white fish to a considerable extent.

Slavin (U.S.A.): I think this is a very good point. Perhaps with the advancement in technology we could use a storage temperature of −40°C (−40°F) or even lower just as easily today as we used −18°C (0°F) sometime ago. I wonder if there is any specific information on actual performance costs.

Persson (Sweden): About two years ago we made a comparison of the cost for a cold store operating at −20°C (−4°F) compared with a store operating at −30°C (−22°F). We found that the difference in investment cost was only about 2 per cent. The difference in cost for electricity, on the other hand, varied about 30 per cent, but as the electricity cost is only a part of the total operating cost, we calculated an increase in operation cost of about 7 per cent.

I think that for practical reasons concerning the people working in the cold store, one cannot aim for a much lower temperature than −30°C (−22°F).

Somma (France): Je voudrais ajouter à ce qui a été dit en ce concerne l'abaissement des températures que les navires également, que ce soit les transporteurs ou les chalutiers congélateurs, progressent rapidement.

Les navires transporteurs sont actuellement construits pour des transports à −28°C (−18°F).

Pour les chalutiers congélateurs, je voudrais citer l'exemple de nouveaux types d'installations pour chalutiers qui comprennent:

(1) Tunnel de congélation à air sur le pont à −40°C (−40°F).

(2) Cale de stockage à −35°C (−31°F).

(3) Tank à eau de mer refrigérée à 0°C (32°F).

L'ensemble de ces équipments a pu être monté sur des chalutiers même petits. Nous avons pu construire des navires de 23 mètres qui avaient tous ces équipments et également des navires beaucoup plus grands. Le prix de ces navires n'a été majoré que de 15 à 20 pour cent.

On peut donc dire que nous avons résolu le problème des basses températures sans augmentations sensibles des prix.

Nous pensons donc que l'adoption de ces procédés sur le plus grand nombre de navires permettra la congélation aussitôt après la pêche et cela résoudra les problèmes de qualité si longuement discutés.

Lorentzen (Norway): Just one small point in connection with the very low temperature in ships' holds. If you have a larger ship you will run up against an economic barrier at -28°C (−18°F) because special non-cold-brittle steel is required below this temperature. If you have 'tween decks or if you have columns, you will have some economic trouble. For this reason I think that in most cases −28°C (−18°F) may be the practical barrier.

Persson (Sweden): As an answer to a question concerning fire regulations, I would like to quote the last lines in my own paper, where I say that ". . . let us also not neglect the fire risk".

Our experience is that local fire regulations vary considerably and it is necessary whenever you plan to build a cold store to discuss the proposed design with local authorities before you let the planning go too far.

As far as insurance goes, one must investigate both the cost for insurance of the building and the insurance of the product. The variation in rates are considerable for various types of constructions, but in most cases the insurance costs are only a minor item in the total cost, and reasonable variations in the insurance cost does not influence the over-all cost very much.

The considerable number of cold store fires over the last years is, however, very alarming and everyone who builds a cold store has a very good reason to seriously consider the fire risk before decision is taken regarding type of cold store construction.

Envasado de Pescado Congelado

por L. Sicre

Envasado de pescado congelado

En este documento se analizan las posibilidades que ofrecen los materiales de envase y embalaje existentes en el mercado español utilizables para pescado congelado, así como la aptitud de las técnicas y las limitaciones de los equipos.

Se discuten asimismo problemas de presentación de envases así como el zunchado y marcaje de embalajes. Se examinan por último las ventajas de la normalización de los embalajes y del uso de tableros de carga para la eficiente y económica manipulación mecánica de los productos congelados.

Packaging of frozen fish

This paper analyses the possibilities of using wrapping and packaging materials presently available on the Spanish markets for frozen fish, and examining the suitability of the techniques and limitations of equipment.

Problems in the use of containers as well as those of sealing and marking packages are also discussed. Finally, the advantages of the standardization of packaging and the use of pallets for efficient and economic mechanical handling of frozen commodities are also examined.

Emballage du poisson congelé

La présente communication analyse les possibilités des matériaux d'emballage et d'empaquetage existant sur le marché espagnol et pouvant être utilisés pour le conditionnement du poisson congelé, puis elle examine dans quelle mesure les techniques sont appropriées et détermine les limitations de l'équipement. Elle fait également le point sur les problèmes posés par la présentation des emballages ainsi que par le cerclage et le marquage des paquets. Enfin, elle étudie les avantages de la normalisation des emballages ainsi que l'utilisation efficace et économique des palettes dans la manipulation des produits congelés.

CON el espectacular desarrollo de la congelación de productos pesqueros, como consecuencia del continuo incremento y modernización de la flota pesquera autocongeladora y de la aplicación de nuevos métodos de procesamiento, los problemas de su envase y embalaje están adquiriendo una importancia fundamental en la preservación, distribución y comercialización de productos congelados de buena calidad.

En este documento se tratan las posibilidades actuales de los materiales para envase y embalaje, de satisfacer los requisitos y necesidades de la industria moderna de pescado congelado en sus formas varias de presentación comercial. Al mismo tiempo se incluyen recomendaciones con particular referencia a la normalización de formatos y a las características de los materiales empleados, complementando la evaluación de los beneficios que la aplicación de métodos modernos de envase y embalaje pueden proporcionar a la creciente industria de pescado congelado.

PREENVASADO DEL PESCADO CONGELADO

Elección de los materiales soporte

En la actualidad no existe una técnica industrial apropiada en el preenvasado de pescado congelado, por lo que la elección de los materiales soporte para una primera manipulación, es práctica que responde pocas veces a una tecnología previamente determinada y empíricamente se resuelve, en cuanto al recubrimiento, por helamiento del propio pescado congelado al ser introducido, en particular, en grandes piezas, en agua helada para formar una capa de protección de agua que evite la oxidación o una simple envoltura generalmente en film de polietileno convencional.

Elección de los materiales de envoltura

Para material de envoltura sólo se ha venido utilizando en la práctica para el pescado congelado troceado de calidad, bien sea papel sulfurizado o bien film de polietileno convencional.

Técnicas de preenvasado

Las técnicas de preenvasado se concentran en la elección de piezas grandes, medianas y pequeñas, y dentro de ello, en las distintas calidades de pescado que determinan o predeterminan una mejor presentación eventualmente.

Equipo

No existe un equipo particular al respecto hasta la fecha.

Marcaje

Hasta ahora la selección de las piezas desde el punto de vista de preenvasado en orden a un marcaje de codificación de las mismas para prepararlas a la operación siguiente que es la de envasado, no está establecida en la práctica de un modo racional de tal manera que simplifique la operación de envasado.

Consideraciones en torno a las manufacturas de envase y sus formatos

Hasta la fecha y ello es práctica general, el pescado congelado se presenta:

(1) Para grandes piezas, generalmente, incluso sin ninguna clase de envoltorio.

(2) Para piezas medianas se envuelven generalmente en films de polietileno convencional.

(3) Para piezas pequeñas se envuelven en film de polietileno convencional o linear, dependiendo de la calidad y el efecto de presentación que se pretenda alcanzar, y a lo sumo, para buenas calidades de pescado y muy en particular para pescado congelado troceado en filetes, se coloca dentro de cajas de cartón compacto, sean parafinadas o revestidas con "hot-melt" (mezcla caliente de ceras).

Las cajas de cartón compacto son litografiadas, generalmente con muy buenas impresiones, realzadas por la aplicación de mezclas de ceras, "hot-melt", o recubiertas las cajas por aplicación directa mediante revestimientos adhesivos, sean de polipropileno o de cloruro de polivinilo en film, o con otros tipos de recubrimiento buscando el realce y mejor presentación de la caja de cartón compacto y, por otro lado, es un perfecto aislamiento y protección contra la humedad exterior, sea producida por congelación o por deshielo en torno, de tal manera que el envase no sufra deterioro y, por consiguiente, tampoco el contenido.

No existe al respecto una normalización en formatos y prácticamente son los tipos de máquinas que existen en el mercado, que realizan generalmente la erección y preparación de la caja para colocación en el interior de los filetes o piezas de pescado, los que determinan los formatos posibles. El número de máquinas que existen en el mercado al respecto, es considerable.

Otros tipos de papel-cartón utilizables en combinación con máquinas, son los de "Texcote", existiendo distintas calidades, según el objeto que se trata de alcanzar con ellas. Calidades especiales de este tipo de cartón compacto se producen en España por distintas empresas.

ENVASADO DEL PESCADO CONGELADO

Elección del material de envase

Ante todo, en el pescado congelado se pretende lograr:

(1) Una perfecta protección contra la oxidación.

(2) Una perfecta protección contra el roce y daño consiguiente del pescado.

(3) Una buena presentación.

(4) Se busca también un material de envase económico.

Al parecer, todas estas exigencias sólo pueden ser reunidas con el material plástico polietileno convencional (alta presión—baja densidad), y para presentaciones de mayor exigencia, con el polietileno linear (alta densidad—baja presión).

Existen tendencias en el envasado de pescado congelado con materiales retráctiles de fácil unión, por no decir termosoldadura, por simple contacto, como pueden ser los materiales tipo resinite de la serie de las poliolefinas, materiales biorientados.

Otro empleo es también el del pvc retráctil sin material tóxico en sus plastificantes.

Características y comportamiento (contenedor-contenido) exigibles

El material de envoltura o material de envase, en este caso, la caja que contenga el pescado congelado ya envuelto tal como se ha indicado en el capítulo anterior, debe evitar:

(1) Toda contaminación de sabor al contenido.

(2) Que su impresión exterior en la caja pueda ser tóxica o pueda traspasar al contenido, con lo cual se alteraría, por lo menos, la presentación.

(3) Debe ser un envase que resista la acción de la humedad ambiente y el contacto en particular con agua producida por deshielo, sea exterior o interior. Perjudicaría la presentación del envase y lo que es peor, su protección con el consiguiente deterioro del contenido.

Estas exigencias se refieren fundamentalmente al aspecto sanitario.

Tipos de manufacturas recomendables

Fundamentalmente se recomienda aquí la caja de cartón compacto litografiada y revestida, como ha quedado indicado anteriormente y ello por razones de economía, de presentación y de facilidad en el manejo de las máquinas adecuadas de erección o de envasado.

En algunos casos, al emplearse equipos que pueden permitir la erección de las cajas y al mismo tiempo la envoltura en film plástico retráctil, se han de tener en cuenta las recomendaciones anteriores para la elección de los materiales adecuados de envasado.

Estos tipos de manufacturas preconizados no excluyen otros que pudieran aparecer en el mercado, como en particular puede ser la caja extrusionada, soplada e inyectada según nuevas técnicas desarrolladas en Alemania, producida en poliestireno.

Otras tendencias pueden ser también la caja extrusionada, soplada e inyectada de polietileno de tipo linear.

Al respecto, el mercado inicia unas tendencias de acuerdo con las investigaciones más recientes en el empleo de estos materiales, todos los cuales son idóneos. Naturalmente, al referirnos al tipo de poliestireno inyectado, estamos hablando de un poliestireno rectificado, de tal manera que en ningún caso produce contaminación de sabor o alteración de sabor al contenido.

Problemas de presentación (grafismo y atracción visual)

Se entiende que en este tipo de mercancías, el problema de la presentación es absolutamente fundamental y básico. En efecto, muchas veces las ventas de productos congelados, y en particular de pescado congelado, no se han producido debido al inevitable mal aspecto que tienen los pescados congelados en el momento de su venta si no se resuelve este aspecto mediante una presentación adecuada que sólo puede ser dotada por un envase adecuado.

Como anteriormente ha quedado indicado, el tipo de presentación puede ser logrado siempre mediante una adecuada litografía de la caja de cartón compacto o una impresión, sea por litografía o por impresión offset por transparencia cuando se emplean materiales plásticos.

La atracción visual y la elección de colores adecuados en función de los países que han de consumir el pescado congelado (puede haber problemas de color de tipo político, de tipo religioso, etc.), y sobre todo, las similitudes subconscientes que establece el comprador entre colores y comportamiento del producto alimenticio, deben ser estudiados en cada caso y para cada país concreto, incluso para cada región, a fin de evitar que las cajas se presenten con un colorido que de antemano el comprador subconscientemente pueda rechazar.

Equipo

El equipo se limita fundamentalmente en estos casos a las máquinas de erección y envasado automático simultáneo cuando se emplean varios materiales laminados conjuntamente o a las máquinas mixtas que trabajan con varios materiales.

EMBALAJE

Elección del material de embalaje

A este respecto poco tenemos que añadir tras hablar del poliestireno expandido. Con las cajas que con su correspondiente tapa se han producido en prototipos recientemente realizados en Alemania, se ha llegado a crear un tipo de caja para transporte de pescado cuyas características presentan respecto a las cajas tradicionales para transporte, las siguientes ventajas:

(1) Absoluta neutralidad en cuanto a la relación contenedor-contenido.

(2) Material perfectamente aislante térmico hasta el punto que garantiza la conservación del frío del pescado congelado, más la eventual adición del hielo, durante tres días más que las cajas tradicionales, de tal manera que se pueden emplear como medio de transporte camiones corrientes sin necesidad de que sean frigoríficos o isotermos.

(3) Otra de las ventajas que reúne este tipo de embalaje es que por su precio puede ser considerado como embalaje regalado, o sea, embalaje de un solo uso, por consiguiente, no retornable.

(4) Otra ventaja es que el material es tan ligero, puesto que el 80 por ciento de su componente es aire, que supone un evidente ahorro en la tara de transporte.

(5) Facil identificación de las cajas, marcaje, etiquetado y zunchado.

(6) Rápida producción de estas cajas mediante equipos no costosos de máquinas para fabricar este tipo de cajas de embalaje.

(7) Perfecta estabilidad y comportamiento frente al apilado, incluso en un número de cajas que rebasara los 5 m (16 ft) de altura.

Otras cajas que pueden emplearse también son las del tipo que ilustra la fig 1. Se trata de un sistema de cajas fabricadas en material plástico polietileno en alta y baja

Fig 1. Tipo de caja utilizable para el transporte de pescado congelado

densidad en las proporciones adecuadas, conteniendo un aditivo colorante que evita el efecto de los rayos infrarrojos de la luz solar, evitándose así el envejecimiento del material y por consiguiente, de la manufactura, y cuyo diseño, sumamente sencillo e ingenioso, permite su transporte llenas, apiladas en los puntos de apoyo que tienen previstos en los ángulos. En vacío, son embutibles, cambiándolas de posición respecto de su colocación para el transporte cuando están llenas, lográndose un máximo aprovechamiento del espacio, para el retorno en vacío, así como en su apilamiento cuando se encuentran en almacén.

La caja, de diseño, concepción y realización española, ha sido producida teniendo en cuenta las necesidades prácticas de los armadores de buques, los sistemas de comercialización y de reparto y la actitud psicológica de los pescadores. Su color, gris, o imitando madera, tiende en esta última versión a mantener en lo posible la tradicionalidad. El sistema de agarre también ha sido concebido teniendo en cuenta la medida exacta de "cuerda", para el manejo cómodo de las cajas. El vertido de agua por descongelación eventual, es sumamente fácil, y las ranuras inferiores permiten por su forma longitudinal, un perfecto desagüe. Unos refuerzos en la parte inferior a modo de vigas, permiten a su vez un fácil deslizamiento. Las medidas previstas son:

Para el tipo "Carioca": $770 \times 500 \times 100$ mm ($30 \times 20 \times 4$ in)

Para el tipo "camión": $770 \times 500 \times 150$ mm ($30 \times 20 \times 6$ in)

En principio, puede adoptarse también la caja de aluminio, siempre que vaya adecuadamente tapada, aunque tiene los inconvenientes de ser embalaje retornable difícilmente embutible, aparte del problema del ruido y del precio de la misma.

Queda, desde luego, totalmente desechada la caja de madera.

Método de envasado del pescado congelado màs utilizado en España

Normalmente las empresas armadoras vienen envasando su pescado congelado en bolsas de plástico que a su vez se introducen en una caja de cartón que se cierra con grapas. El peso total de la caja varía entre 18 y 22 kg (40 y 48 lb), llena.

Estas cajas no difieren grandemente de unas a otras empresas aunque no puede decirse que estén totalmente normalizadas.

Para el marisco se hacen, en principio, cajas de material similar y de un peso aproximado de 10 kg (22 lb). Sin embargo, en este sector la diferencia de envases es mucho más acusada por razones de comercialización y los tamaños varían según las empresas armadoras, pues hay unas que los utilizan de 5 kg (11 lb) e incluso de menos peso.

En este sector, el material de embalaje está siendo objeto individualmente de estudios para adoptar el más conveniente según la propia estimación de cada empresa.

Aspectos de la normalización del embalaje

A este respecto es de lamentar que no exista hasta la fecha, al menos en España, una normalización en el embalaje de pescado congelado. La tendencia es que la normalización sea conforme a las normas recomendables por el proyecto ISO 435 y la Comisión correspondiente de normalización que se corresponde con las normas españolas UNE nos 49.900, 49.901, 49.902-h1 y -h2, 49.903-h1, -h2 y -h3, 49.904 y 49.905-h1 que se refieren a los tableros de carga. Por consiguiente, aplicando el sistema modular aprobado por la Federación Europea del Embalaje, se pueden lograr tipos de embalaje

adecuados a los tableros de carga recomendados por ISO y por la Federación Europea del Embalaje.

Llenado mecánico de las cajas

En lo posible, las cajas deben ser llenadas en forma lo más automática posible, sin que ello vaya en detrimento de la calidad de pescado, a fin de evitar que sufra traumas o golpes que en el estado en que se encuentra el pescado, producirían roturas, deshaciendo totalmente el posible buen aspecto de la mercancía. Se preconizan como los más adecuados, los sistemas de llenado semiautomáticos, empleando caminos de rodillos o bandas transportadoras y llenando las cajas por operarios a medida que se van presentando ante ellos a partir de los suministros que pueden realizarse por tolva y banda inclinada hasta los puntos de llenado haciendo deslizar la mercancía o, eventualmente, bandas transportadoras deslizantes, siendo preferible que el punto de llenado se logre en cuanto a su abastecimiento por gravedad.

Zunchado y marcaje

Si se emplean las cajas de poliestireno expandido, el zunchado se hace con cinta adhesiva reforzada con fibra de vidrio en sentido longitudinal, siendo aconsejable el empleo de estas cintas con material soporte, sea celofán, sea pvc. El conjunto de cajas puede unirse también con cinta adhesiva reforzada con fibra de vidrio, siempre que se emplee el poliestireno expandido.

Si se emplean cajas del tipo de otros materiales plásticos o cajas metálicas de aluminio, el zunchado puede realizarse por fleje de polipropileno o por fleje de acero, con cantos matados, es decir, fleje con arreglo a normas (en España tenemos la norma UNE, no 89.801), pudiéndose emplear equipos mecánicos, herramientas de flejar manuales o semiautomáticas. Preferiblemente en este tipo de trabajo úsense herramientas manuales, sean accionadas mecánicamente o por aire comprimido, de tal manera que el conjunto de cajas quede unido al tablero de carga para simplificar y asegurar las operaciones de carga, descarga y estiba, con las correspondientes paletas y el manejo mecánico de las mismas por carretillas elevadoras.

También puede emplearse fleje de nylon.

El marcaje debe efectuarse de tal forma que el conjunto de carga conozca perfectamente su destinatario y su expedidor, unidades que contiene, peso bruto, unidades de envases con la indicación de si son retornables o no.

El marcaje puede hacerse semiautomáticamente o automáticamente, empleando los varios sistemas existentes.

Aplicación de los tableros de carga para manipulación mecánica

Es recomendable la aplicación de los tableros de carga de acuerdo con las normas ISO reproducidas en España por Normas UNE, Nos. 49.900, 49.901, 49.902-h1 y -h2, 49.903-h1, -h2 y -h3, 49.904 y 49.905-h1.

De esta manera, se puede asegurar la perfecta manipulación de las operaciones de carga y descarga y estiba del pescado congelado con perfecta protección de los envases del mismo, de sus envolturas y de la mercancía, asegurando también un movimiento máximamente económico de esta mercancía.

ANEXO 1

Legislación española sobre pescado congelado

La legislación fundamental viene dada por la Orden de 31 de enero de 1955 (Ministerio de la Gobernación) que establece el Reglamento Sanitario de mataderos y almacenes frigoríficos y de circulación de carnes y pescados frescos, así como por la Orden de 24 de septiembre de 1956 (Ministerios de la Gobernación y Comercio) que contiene las normas sanitarias en capturas, comercio y abasto.

Respectivamente, en lo que se refiere a envase y embalaje, dicen:

ORDEN 31-1-55

Art. 31. . . . las cajas que sirvan de envase contendrán un 10 por ciento como mínimo, del peso del pescado, de hielo triturado o en escamas.

Art. 32. El transporte desde los almacenes frigoríficos o desde las lonjas se efectuará en envases metálicos inoxidables, o de madera limpia, en los que se acondicionará el pescado fresco con hielo triturado o en escamas en la proporción de 1 kg de hielo por cada 2 kg de pescado.

Los medios de transporte serán vagones o camiones isotérmicos si el viaje es superior a 12 horas.

Cuando la duración del mismo rebase las 24 horas, los vehículos mencionados irán provistos de refrigeradores propios.

Art. 33. A la llegada del pescado a destino se concentrará en un mercado de recepción para el reconocimiento por el veterinario titular de servicio, y se subastará si procede con toda rapidez, o se distribuirá a los detallistas con el mismo sistema de envasado y conservación con hielo expuesto en el Art. 32.

Art. 35. Cuando el pescado haya de consumirse pasado un plazo de 12 días de su llegada a puerto, será sometido a congelación rápida a $-23°C$ ($-10°F$) en un lapso de tiempo de 12 horas (en túneles con corriente forzada), pescados enteros (congeladores de placas de contacto en pescado troceado).

Almacenamiento máximo: 8 meses.

Art. 36. Durante el almacenamiento en cámaras frigoríficas circulará una corriente forzada de aire frío y una vez al mes, por lo menos, será sumergido el pescado en piezas enteras, en agua helada, que, al congelarse rápidamente, le envuelva en una película de hielo que impida los procesos de oxidación. El pescado troceado en filetes será empaquetado con papel impermeabilizado y no sometido a la inmersión anterior.

ORDEN DE 24-9-56

Art. 3°. El lavado, faenado y envasado del pescado para su transporte (lugares y locales higiénicos). Los envases reunirán condiciones de sanidad convenientes y los que se usen más de una vez, serán limpiados y desinfectados debidamente.

ANEXO 2

Recomendaciones para el tratamiento, conservación y transporte por el Frío, de productos alimenticios perecederos. Secretaría General. Gabinete Técnico de Alimentación. C.A.T., págs. 85 y 86, mayo 1965.

Las especies de gran tamaño se manipularán a granel, es decir, no irán colocadas en embalajes especiales.

Las especies pequeñas, filetes o rodajas de pescado, deberán introducirse, con anterioridad a su congelación, en embalajes adecuados.

Se admitirán aquéllos que sean impermeables al vapor de agua y al aire, que proporcionen un cierre hermético y que no sean tóxicos.

A tal fin, podrán utilizarse cajas de cartón parafinado, protegidas exteriormente con una envoltura de papel encerado o similar, con el fin de que haya cierre hermético.

Los filetes de pescado podrán envolverse individualmente o en bloque, en envolturas de acetato de celulosa impermeabilizado, polietileno, cloruro de polivinilideno o similares y colocarse en el interior de cajas de cartón parafinado o bien introducirse directamente en bolsas de los mencionados productos plásticos, procurando quede en el interior la menor cantidad posible de aire antes de proceder a la soldadura, siendo recomendable cerrarlas al vacío, sobre todo en el caso de que se trate de pescados grasos.

Todos los envases para venta al por menor, deberán ir provistos de instrucciones para llevar a cabo una descongelación y empleo apropiados por parte del consumidor.

Experience with Modern Packaging

by C. A. Almarker

Experience with modern packaging

The required physical properties of packaging materials are outlined in general. Water vapour and heat radiation barrier properties are discussed in particular. Assuming a maximum cold storage period of 400 days and using previously determined estimates of critical moisture losses for different frozen foods, the author calculates the maximum permissible water vapour diffusion rates for packaging material to be 0.15 to 0.27 g/m² 24 h (3×10^{-5} to 5.4×10^{-5} lb/ft² 24 h) for frozen fish, 0.20 to 0.27 g/m² 24 h (4×10^{-5} to 5.4×10^{-5} lb/ft² 24 h) frozen peas and spinach and 0.35 to 0.52 g/m² 24 h (7×10^{-5} to 10.4×10^{-5} lb/ft² 24 h) for frozen beans. Extensive tests have shown the paper boards coated both sides with polyethylene have water vapour diffusion rates well within these limits. The bleaching and drying effect on packaged frozen food of radiation from lights in retail stores is also discussed. The incorporation of aluminium powder in the adhesive used in bonding two film materials appears to be a very promising method of providing a light and heat radiation barrier.

L'expérience concernant les emballages modernes

L'auteur décrit brièvement les propriétés physiques demandées aux matériaux d'emballage. Les propriétés en matière de rétention de la vapeur d'eau et du rayonnement thermique sont examinés plus en détail. Se fondant sur l'hypothèse d'un entreposage de 400 jours et sur des évaluations antérieures de la quantité critique d'exsudat pour différents produits alimentaires congelés, l'auteur établit entre 0,15 et 0,27 g/m²/24 h (3×10^{-5} à 5.4×10^{-5} lb/ft² 24 h) le taux maximum admissible pour la diffusion de vapeur d'eau pour le poisson; les valeurs correspondantes pour les petits pois et les épinards, ainsi que pour les haricots verts congelés s'établissent entre 0,20 et 0,27 g/m²/24 h (4×10^{-5} à 5.4×10^{-5} lb/ft² 24 h) et entre 0,35 et 0,52 g/m²/24 h (7×10^{-5} à 10.4×10^{-5} lb/ft² 24 h) respectivement. Des expériences poussées ont montré que pour les emballages de bristol en sandwich entre deux pellicules de polyéthylène le taux de diffusion de la vapeur d'eau reste bien inférieur à ces limites. L'incidence du rayonnement lumineux sur la décoloration et le dessèchement des produits alimentaires congelés et emballés est également examinée. L'incorporation de poudre d'aluminium à l'adhésif utilisé pour joindre deux pellicules semble devoir constituer un obstacle efficace à la chaleur et au rayonnement thermique.

Experiencia adquirida con el envasado moderno

Se indican en general las propiedades físicas que necesitan los materiales de envasado. Se examinan en particular las propiedades de impenetrabilidad del vapor de agua y de las radiaciones térmicas. Suponiendo un período máximo de almacenamiento frigorífico de 400 días, y valiéndose de estimaciones previamente determinadas de pérdidas críticas de humedad en diferentes alimentos congelados, el autor calcula que las tasas máximas permisibles de dispersión del vapor de agua son de 0,15 a 0,27 g/m²24 h (3×10^{-5} a 5.4×10^{-5} lb/ft² 24 h) para el pescado congelado, 0,20 a 0,27 g/m²24 h (4×10^{-5} a 5.4×10^{-5} lb/ft² 24 h) para los guisantes y espinacas congelados y 0,35 a 0,52 g/m²24 h (7×10^{-5} a 10.4×10^{-5} lb/ft² 24 h) para los frijoles congelados. Numerosas pruebas han demostrado que los cartones revestidos por ambos lados con polietileno poseen tasas de difusión del vapor de agua que se hallan dentro de estos límites. Se examina también el efecto descolorante y desecador que ejerce la irradiación de las luces de las pescaderías sobre los alimentos congelados envasados. El empleo de polvo de aluminio en el adhesivo que se usa para unir dos trozos de película, parece que constituye un método muy prometedor que proporciona una barrera contra la irradiación de la luz y el calor.

PACKAGES for frozen foods must meet the same requirements as other high quality packages. There are in addition some special requirements for frozen food products, including fish. These may be indicated as follows:

(1) Barrier properties; impermeability to:
  (a) liquids
  (b) water vapour
  (c) oxygen
  (d) aroma substances
  (e) light and heat radiation.

(2) Mechanical properties: rigidity and strength with regard to cubic expansion during freezing and thawing.

(3) Use and handling properties: good heat transfer—must permit quick freezing of contents, suitability for modern packaging machines—must be practical and convenient to handle during storage and transportation and convenient to open and reclose.

(4) Miscellaneous:
  (a) the material must not cause odours or off-taste;
  (b) it must be approved by food authorities;
  (c) it must protect against fouling and infection;
  (d) in some cases the package should withstand heating;
  (e) it must have good printability and the printed surfaces must withstand normal handling during production, storing and distribution.

It is obvious that, in general, most packages for frozen fish products comply with these requirements. However, in recent years packaging materials and package designs for frozen fish products have been improved to the extent that liquid-tight and moisture vapour-proof packages have been achieved. More experience has also been obtained about the influence of heat radiation during storage of frozen foods in freezer display cabinets. It may, therefore, be of interest to discuss the properties of these rather new plastic-coated cardboard materials and also packaging equipment by which such packages are handled. Further, the influence of heat radiation caused by light on frozen food in plastic film packages stored in retail freezing cabinets will be discussed.

IMPERMEABILITY TO LIQUIDS

A package for frozen fish products must be liquid proof, since before freezing such products sometimes contain juice or brine that has a low freezing point. Twenty to

30 per cent of the water may not be frozen even at as low a temperature as −60°C (−76°F). The time between the packaging and the freezing can, therefore, be critical, as can the time between the beginning of the thawing and consumption.

The liquid from fish products may also have a low surface tension and consequently wet packaging materials and readily penetrate the smallest flaw or break in the material.

Small leaking points can, in some cases, result from volume expansion at freezing. Therefore, it has been regarded as too difficult to develop a package design made from paper board that is 100 per cent leak-proof in practice. The difficulties in this connection have been increased by the fact that most paper board packages for fish products which are packed wet, must have a rather shallow form and be of the so-called open-top design, both for quick freezing and to allow filling of the products from the top of the carton, i.e. the open area for filling is the top side and has the largest surface. However, by using a two-side polyethylene-coated paper board and a special design for the corners of the carton, Åkerlund and Rausing, Sweden, have succeeded in developing a completely watertight bottom part for the open-top carton. This carton, starting from a flat blank, is erected on a machine which forms the carton by using the PE-coating as the sealing medium to form a liquid-tight base or tray part, which is filled on a conveyor belt from the erecting machine and is then sealed by connecting three flaps from the carton lid to three sides of the bottom. For this sealing operation, a hot melt adhesive dispensed from rolls (Thermogrip) is used to obtain such a tight seal that the carton is almost leak-proof when turned upside-down on its lid. This type of carton is in large volume commercial use in a number of European countries, and is regarded by the frozen fish processing industry and also by producers of a range of other frozen food products, such as spinach, beans and many other vegetables, to be a good answer to the demand for a top-opened package, liquid-tight at the base during packaging operations and initial stage of freezing.

MOISTURE VAPOUR BARRIER PROPERTIES

A frozen food product can lose water by sublimation (evaporation from the frozen state), if this is not prevented by a functional, moisture vapour-proof package. The lowest ambient temperature in the cold store is at the heat exchanger and this results in a condensation of moisture vapour in the form of ice crystals on the freezing elements. This leads to dehydration of the air surrounding the freezing element. In this way, the water vapour concentration gradient is built up and that, together with air movement and temperature differences, makes possible a continuous transportation of water from the food to the freezing elements, and desiccation of the product follows.

The water evaporation that takes place from the surface of the products causes the texture to become porous owing to the fact that the water diffusion from the centre of the frozen product is too slow to compensate for the loss of moisture from the surface. With this porous structure, fat rancidity may be accelerated.

However, even when using a functional, moisture vapour-proof package, the loss of quality known as freezer burn can occur. By nature freezer burn is principally a desiccation phenomenon. Conditions for the development of freezer burn are voids between the product and package surface and fluctuations in temperature. A deposit of moisture vapour in the form of ice crystals will occur on the coldest area of the inside package surface. At a subsequent increase in temperature, the enclosed volume of air will absorb further water from the food which will again be deposited as ice crystals on the inside of the package. In such a way, with repeated fluctuations in temperature, a pronounced local desiccation takes place and oxygen from the air further increases the quality-damaging processes.

The above-mentioned processes are, no doubt, well known to all processors of frozen fish products and other frozen food. They have been mentioned, however, in order to show how important it is to consider product quality problems when choosing packaging materials.

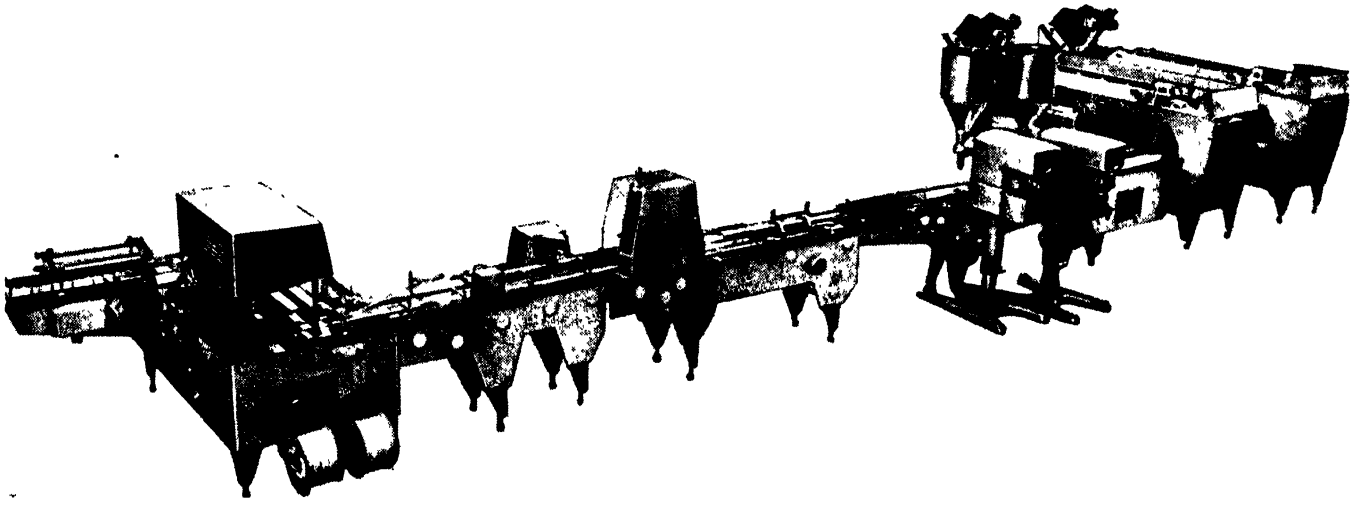


Fig 1. Packaging line for wet products (frozen after filling) consisting of the following components (from right to left): two Sta-Lox Super Seal erecting machines; one filling station; one synchronizing unit; one trampler unit; one code marking unit; one dust-flap folder; one TS III lid closer with Thermogrip units. Capacity: up to 110 cartons/minute

Different frozen foods have different requirements for moisture vapour permeability in order to avoid desiccation.

The critical loss of water through package surfaces can be expressed as weight loss per unit area. Heiss and his group have been able to establish the following figures:

Fish	60 to 110 g/m^2 (1.2×10^{-2} to 2.2×10^{-2} lb/ft^2)
Peas and spinach	80 to 110 g/m^2 (1.6×10^{-2} to 2.2×10^{-2} lb/ft^2)
Beans	140 to 210 g/m^2 (2.8×10^{-2} to 4.2×10^{-2} lb/ft^2)

The question arises of how long it will take for different types of packages before this figure is reached. For some products it is just a couple of months, for others perhaps one year or a little more.

If it is required that critical desiccation does not occur during 400 days of frozen storage, the highest permissible rate of moisture vapour migration in 24 h can be easily calculated. Using the above-mentioned figures, the following values will be obtained:

Fish	0.15 to 0.27 g/m^2 24 h (3×10^{-5} to 5.4×10^{-5} lb/ft^2 24 h)
Peas and spinach	0.20 to 0.27 g/m^2 24 h (4×10^{-5} to 5.4×10^{-5} lb/ft^2 24 h)
Beans	0.35 to 0.52 g/m^2 24 h (7×10^{-5} to 10.4×10^{-5} lb/ft^2 24 h)

Extensive laboratory tests made by Åkerlund and Rausing, Sweden, have shown that moisture vapour migration through consumer packages made from two-side polyethylene-coated board is four to 20 times lower than required to avoid freezer burn during 400 days' storage. Frozen food packages made from two-side polyethylene-coated board, are rapidly growing in use by leading frozen food processors in Europe, including among others Unilever and Findus-Nestlé. In the frozen fish field, top-opened cartons of two-side polyethylene-coated board are becoming more and more appreciated.

PROTECTION AGAINST LIGHT

Losses of quality (bleaching of products in combination with drying of the surface) can result from light and by infra-red radiation causing a rise in temperature at the exposed parts of the package. This happens principally in retail frozen food cabinets and particularly with pouch and bag form packages made from transparent films and combinations of such films. Appreciable differences in temperature can occur, especially where parts of the surface are unprinted or where the ink layer is not capable of reflecting light and infra-red radiation. Bag and pouch packages should therefore have a layer that will reflect light and radiation. Very promising results have been achieved by using aluminium powder in the form of an ink which is applied to the film at the time the labelling and decoration is printed. Preferably, such an aluminium powder ink layer should be used with a laminated material and applied as a reverse print. AB Åkerlund and Rausing, Sweden, has applied for patents for this principle in various countries. Pouches as described above are used by one of the leading frozen food processors in Sweden for packaging cod fillets on a large commercial scale and the results are satisfactory.

However, for fatty fish products, the aluminium powder layer in bags and pouches does not give sufficient protection against quality losses due to rancidity, since these are caused by the influence of both air oxygen and light. To avoid such losses in quality it is necessary to pack the products in gas-tight pouches with as high a degree of vacuum as possible.

State of the Art and Problems of Frozen Fish Packaging

by R. Heiss

State of the art and problems of frozen fish packaging

The paper surveys the packaging material presently used for frozen fish products. It covers handling and packaging methods on board freezer trawlers, as well as on shore. It is mentioned that modern packaging materials have little influence on the freezing time required for fish fillets. In dealing with the technical requirements for the packaging of frozen fish the relation between water vapour permeability of the packaging material and the occurrence of freezer burn is discussed. If a storage time of nine months at −20°C (−4°F) and a relative humidity of 75 per cent are required, vapour permeability of the packaging material should not exceed 0.22 to 0.37 g/m² in 24 h. Polyethylene (PE) films and cartons waxed on both sides and wrapped in heat-sealable waxed paper are very satisfactory. The present trend seems to be a carton coated with PE film on both sides and sealed by a hot air-blast.

The paper also discusses the influence of packaging materials, packaging methods and storage conditions on the quality of lean and fatty fish. In this connection it is emphasized that more attention should be paid to the development of vacuum packaging. The packaging of frozen fish still presents numerous technical, economic and scientific problems. It is the opinion of the author that it would be rewarding to convene an international meeting to provide an opportunity for an exchange of information on the actual turnover time and temperature relationship observed in particular cases, on costs, on experience with various packaging methods and machines and on possible improvements in the distribution chain.

Situation actuelle et problèmes relatifs à l'emballage du poisson congelé

Cette communication passe en revue le matériel d'emballage utilisé à l'heure actuelle pour le poisson congelé. Elle traite des méthodes de manutention et de conditionnement employées à bord des chalutiers congélateurs et dans les installations à terre. On y indique que les matériaux modernes d'emballage ont peu d'influence sur le temps de congélation requis pour les filets de poisson. S'agissant des exigences techniques auxquelles doit répondre l'emballage du poisson congelé, on étudie le rapport entre la perméabilité du matériel d'emballage à la vapeur d'eau et l'apparition de "brûlures" provoquées par le congélateur. S'il est nécessaire de prévoir une période de stockage de neuf mois à −20°C (−4°F) et une humidité relative de 75 pour cent, la perméabilité à la vapeur du matériel d'emballage ne devrait pas dépasser 0,22 à 0,37 g/m² en 24 heures. Les films de polyéthylène et les cartons enduits de cire des deux côtés et enveloppés dans du papier ciré qui peut être scellé à chaud sont d'un emploi très satisfaisant. Il semble que l'on ait actuellement tendance à utiliser un carton recouvert des deux côtés d'un film de polyéthylène et fermé au moyen d'un courant d'air chaud.

On étudie en outre dans cette communication l'influence des matériaux et des méthodes d'emballage, ainsi que des conditions de stockage, sur la qualité du poisson gras et du poisson maigre. On souligne à cet égard qu'il conviendrait de se préoccuper davantage de développer l'emballage sous vide. L'emballage du poisson congelé pose encore de nombreux problèmes techniques, économiques et scientifiques. D'après l'auteur, il y aurait avantage à convoquer une réunion internationale qui permettrait un échange de renseignements sur le rapport entre le débit réel des ventes et la température constaté dans certains cas particuliers, les coûts, résultats obtenus avec diverses méthodes et machines d'emballage et les éventuelles améliorations à apporter à la chaîne de distribution.

Situación actual y problemas relativos al envasado del pescado congelado

En este estudio se examina el material que se emplea actualmente para envasar el pescado congelado. Se ocupa de los métodos de manipulación y envasado tanto a bordo de los arrastreros congeladores como en tierra. Se indica que los modernos métodos de envasado influyen poco en el tiempo de refrigeración que necesitan los filetes de pescado. Al tratar de las necesidades técnicas del envasado del pescado congelado se examina la relación existente entre la permeabilidad al vapor de agua del material de envasado y la aparición de quemaduras por congelación. Si es necesario un período de almacenamiento de nueve meses a −20°C (−4°F) y una humedad relativa del 75 por ciento, la permeabilidad al vapor del material de envasado no debe pasar de 0,22 a 0,37 g/m² en 24 horas. Son muy satisfactorias las películas de polietileno y las cajas de cartón encerado por ambos lados y envueltas en papel encerado termocerrable. La actual tendencia parece orientarse hacia la caja revestida con una película de polietileno por ambos lados, y cerrado mediante una corriente de aire caliente.

Se examina también la influencia de los materiales y métodos de envasado, y las condiciones de almacenamiento sobre la calidad del pescado magro y graso. A este respecto se pone de relieve que debe prestarse más atención al desarrollo del envasado al vacío. El envasado del pescado congelado presenta todavía muchos problemas técnicos, económicos y científicos. El autor cree que sería ventajoso convocar una reunión internacional que ofreciera la oportunidad de intercambiar información sobre la relación real observada en casos particulares entre el tiempo de conservación y la temperatura, sobre los costos, sobre la experiencia obtenida con los distintos métodos y máquinas de envasado y sobre posibles mejoras en la cadena de distribución.

THAT there is hardly any recent literature on the packaging of frozen fish may either be attributed to the fact that all problems in this field of endeavour have been solved, or that this problem has not yet found the attention it merits. An extensive correspondence undertaken as a preparation for the moderation of a discussion group at the FAO Technical Conference on the Freezing and Irradiation of Fish, Madrid, 4th to 8th September 1967, showed the latter view to be more likely. The following is a comprehensive report on the results of preliminary investigations.

CUSTOMARY PACKAGING METHODS

Interim packaging aboard ship

Fish may be frozen aboard German freezer trawler vessels either whole or as fillets. If fish such as cod or redfish is intended for curing, it is generally frozen whole, without heads, in vertical plate freezers. However, fish intended for marketing as fillets can conveniently be frozen as such aboard the vessel. Filleting can be done by machine, either before or after *rigor*, and the machines are not hampered by rough weather any more than the fishing operation.

Frozen fish blocks. These are produced in various sizes ranging from 15 to 30 kg (33 to 66 lb) in weight. During their production, care must be taken to prevent fillets from sticking to the freezer plates, to prevent air pockets forming in the blocks, and to ensure that the block dimensions are kept uniform.

If vertical plate freezers are used, the fillets are packed in cartons previously placed in the freezer compartments.

The cartons are made from sulphate boxboard which has both sides either waxed or polyethylene (PE) coated. In the case of horizontal plate freezers, a frame of corrugated cardboard is used and sheets of PE film or paper waxed on both sides are used to separate the fillets from the freezer plates. The pre-packaged frozen fish are then stored on board until the vessel reaches port, possibly in up to three months' time. The blocks are subsequently sawn into portions on shore and repackaged in small consumer packages. Occasionally they are thawed, the fillets inspected a second time for bones, and refrozen in consumer packages.

Large fish. Tuna and other large fish are glazed with water after freezing and are stored whole.

Consumer packages

Consumer packaging, a procedure recommended in inshore fishing, is rarely done at sea because the motion of the ship precludes precise weighing. Developments in this direction are under way but providing the necessary manpower on board ship may be difficult. From seven to ten workers are required to fill 100 cartons/min with unfrozen fillets. It seems doubtful whether this procedure can be called economical.

Sawn fish portions. These should be wrapped in a shrunk-on bi-axially oriented plastic film, such as polyvinylidene chloride (PVDC) or, as a substitute, PE. Occasionally, however, the portions are placed, by machine, between two cellophane PE sheets, or, in order to avoid heat-sealing, in cold-sealing paper (PVDC-coated paper), and then sealed (flow pack). For manual packaging of 100 cartons/min, three or four women are required.

If the fillets are to be fried by customary methods, without prior thawing, they should not be thicker than 16 to 20 mm ($\frac{5}{8}$ to $\frac{7}{8}$ in); for boiling, the corresponding values are 22 to 24 mm (1 in).

Unfrozen or thawed fillets. PE pouches or highly moisture-proof grade cellophane (MSAT) or polypropylene film wrappings are generally used for unfrozen or thawed fillets. The outer package is a duplex carton, the outside white and waxed, the inside grey and coated only when the fish is loosely wrapped. It is not hermetically sealed.

Packaging machines. How far one should go in the automation of packaging machines depends on the extent to which they can be utilized. At a favourable rate of utilization, 90 per cent of the cost of a finished package will be accounted for by the cost of the packaging material.

Carton types. The most commonly used are: one-piece folding carton, hook-and-slit design; one-piece folding carton, hot-melt sealed; one-piece flat carton with PE-coated bottom which can be heat-sealed so that drip-tight corners are produced, the three lid flaps being sealed with hot-melt after the box has been filled; carton with overwrap.

The most prevalent packaging machine systems are: machines for the setting-up of cartons (output from 30 to 120/min); machines for closing or sealing of cartons (output from 30 to 200/min); packaging lines with automatic filling machine (output from 30 to 400/min).

TECHNICAL REQUIREMENTS FOR THE PACKAGING OF FROZEN FISH

The basic purpose of such a package is to prevent contamination of the product; in addition it should look attractive, provide a suitable medium for advertising and be sufficiently cheap. It goes without saying that none but toxicologically impeccable packaging materials must be used. There may be difficulties concerning odour, e.g. if the grey inner layer of the duplex is not free from odour when wet.

Other technical requirements are, that the package should not appreciably lengthen the freezing time, that it should protect the contents from deterioration through sublimation and oxidation, and that its surface should not take on any smell of fish.

Packaging requirements in relation to freezing

The different packaging materials in common use nowadays have little influence on freezing times for fillets of customary thickness. More worthy of attention is the fact that freezing times have to be extended if air pockets form between freezer plate and wrapping material, the different layers of the wrapping material, or wrapping material and fillets. Since the thermal conductivity of air is very low [$\lambda = 0.018$ kcal/m²h°C at -30°C (0.0032 Btu/ft²h°F at -22°F)], its heat transmission resistance is very high. The influence of air pockets is greater for thinner blocks and high freezing rate (Kiermeier *et al.*, 1944).

Packaging requirements in relation to contents

Water vapour permeability and freezer burn. Excessive water vapour permeability is one of the causes of freezer burn. To avoid freezer burn, the weight loss in the course of the turnover time should be kept down to about 60 to 110 g/m² (1.2×10^{-2} to 2.2×10^{-2} lb/ft²). Assuming nine months' storage at -20°C (-4°F) and a relative humidity of 75 per cent in the cold store, water vapour permeability should not exceed 0.22 to 0.37 g/m²24 h (4.4×10^{-5} to $7{\cdot}4\times10^{-5}$ lb/ft² 24 h) (Heiss, 1963). Under the above-mentioned storage conditions, a 30 μm PE film has a water vapour permeability of only 0.025 to 0.040 g/m² 24 h (5×10^{-6} to 8×10^{-6} lb/ft²24 h) which is very satisfactory. The corresponding values for cartons waxed on both sides wrapped in heat-sealable waxed paper are only slightly higher: 0.05 to 0.06 g/m²24 h (1×10^{-5} to 1.2×10^{-5} lb/ft²24 h). These figures presuppose heat-sealed packages; mere wrapping without sealing results in a much higher water vapour permeability and does not afford sufficient protection against freezer burn and hence should be avoided. Waxed cartons without overwrap have a water vapour permeability of 3.1 to 3.4 g/m²24 h (6.2×10^{-4} to 6.8×10^{-4} lb/ft²24 h), which is unsatisfactorily high. Mixtures of waxes with Elvax and PE are used to coat cartons; they provide a good gloss. Adding Elvax to the mixture generally increases water vapour permeability. Water vapour permeability of folding cartons, hook and slit design, is always unsatisfactory where no sealed overwrap is provided. Cartons with heat-sealed closures are also sturdier. Inner carton coating is generally made of PE film. Closures are effected with "Hotmelt" which is, for small series, printed on the cartons, or otherwise directly

added in the packaging machine in a way to realize a tight sealing of all corners. In the first case, the "Hotmelt" is reactivated by a hot air blast. The present trend seems to be a carton coated with a PE-film on both sides and sealed by a hot air blast.

The second and more dangerous cause of freezer burn is the above-mentioned air pockets, especially near sharp edges or corners where the sublimation rate is highest. The decisive factor for the appearance of freezer burn is the amplitude and frequency of the temperature fluctuations (Heiss, 1951). Since, according to Scandinavian investigations, frozen fish fillets may be kept for six weeks (one month to three months) in display freezers with average temperatures often not below −15°C (5°F), it is hard to avoid fairly large temperature fluctuations caused, e.g. by rummaging in the display cabinet. Temperature differences of up to 15 degC (27 degF) between the top and bottom of a package have been observed. Thus the hazard of freezer burn is especially high in this last part of the freezer chain if the air pockets within the package are not eliminated as far as possible. To this end, the packages must be completely filled. Since the transfer of heat by convection is about equivalent to the transfer of heat by radiation, when there is no air current, heat exchange may be reduced by introducing an outer aluminium foil layer. As another alternative, water-vapour-proof film may be shrunk on (shrink wrapping), or the package evacuated. One argument against this is that water expands on freezing so that a tightly-filled package might burst. However, experience has shown that, provided the packaging material is sufficiently elastic and pliable, it may bulge, but hardly ever tears (Heiss, 1963). Frozen blocks that are merely inserted into a PE-coated carton are surrounded by an air space which has a detrimental effect.

Even a highly water-vapour-proof carton has pin holes at its corners which means that it is not oxygen tight. This is an advantage during freezing because the air can escape as the contents expand. Very small pin holes do not significantly affect water-vapour permeability. Larger leaks, however, must be avoided not only on account of freezer burn, but also because of the drip hazard when the product begins to thaw in the consumer's shopping bag. Too much need not be made of the latter hazard since shopping is now increasingly being done by car and households are acquiring more and more facilities for storage at lower freezing temperatures. The use of PE pouches without an outer carton is not advisable because, in time, the ice crystals will pierce the unsupported PE film (cold flow). The fish will also be exposed to light in the display freezer.

When the side of the package facing the freezer plate or the fish consists of PE or wax, or is silicone-treated, there is no danger of sticking.

Influence of oxygen. Little scientific literature is available on the possibilities of increasing the shelf-life of frozen fish sensitive to oxidation. Yet it is for this very reason that herring, mackerel, sardines, salmon and ocean perch will keep in high quality for only two to three months when stored at −18°C (0°F), or for six months at −30°C (−22°F), and lobsters and crabs for only two months at −18°C (0°F) (Anon., 1964). The author's own experiments with ocean perch have shown that storage at low oxygen partial pressure does appreciably lengthen the shelf-life of the fish. However, the experimental results scattered widely for different fillets and even for muscles of the same fish. On the other hand, Bramsnaes and Sørenson (1960) have demonstrated that rainbow trout, which very quickly become rancid on the inside of the belly flaps and particularly along the fine blood vessels, will keep for nine months if vacuum-packaged in PE-laminated cellophane and stored at −20°C (−4°F). Promising results have been obtained in South Africa with pilchards packed in alginate.

Fried fish fingers, while obviously having a higher fat content, are in no way more sensitive to oxidation than the unfried fish. In this case, there is no danger either of freezer burn or thaw-drip, and they can be packed safely in PE-coated cartons without any overwrap.

DEVELOPMENT TRENDS AND GAPS

Fillet texture

Frozen fillets are often inferior to chilled fillets because of their more or less woolliness (toughness), the degree of which depends mainly on storage temperatures and on the time in cold storage. Woolliness cannot be improved by changing the package design. In order to keep woolliness within tolerable limits, storage temperature at wholesalers must be lower than −25°C (−13°F) and at retailers not higher than −18°C (0°F).

Packaging aboard ship

It seems that an important step forward would be the production of consumer packages on board ship without the necessity of sawing frozen blocks. Since rough seas preclude precise weighing, portioning by volume will be the only practicable method. Other obstacles are the necessity of prior stowage until *rigor mortis* has passed and the large personnel needed for packaging fresh fillets by hand. Development of machinery for automatic packaging is under way and this will greatly speed up the handling and portioning operations for mass production of frozen fish fillets.

Single-wall packages

Another desirable development from the standpoint of rationalization would be the greater use of tight single-wall packages — wherever they are suitable for the packaged product—with the carton giving the package the necessary strength and the coating protecting against water vapour loss. However, gas tightness cannot be achieved with such packages and freezer burn can be avoided only if no air pockets remain after filling. The outer layer must be resistant to abrasion.

Frozen fatty fish

Frozen fatty fish does not always reach the market in good condition. In the case of ocean perch, for instance, this is often due to the length of the fishing trip and because there are economic limits to the extent to which storage temperatures can be lowered. Although long turnover times at the end of a fishing voyage require large capital outlays, the maxim of "first in, first out" cannot always be followed in actual practice. Even at

−30°C (−22°F) there is no guarantee, if turnover times are long, that fatty fish will still be in good condition when it reaches the consumer—not to mention the fact that during some part of the turnover period temperatures will be higher. In these circumstances there seems to be a case for a package with low oxygen partial pressure in order to prevent oxidation and rancidity. Here more knowledge from fundamental research is required. For trout we do have convincing research results, but they are hardly applied. Similarly, interest in this kind of packaging for matje's cured fillets (Anon., 1958) has died down. Conceivably the growing practice of compulsory indication of packing dates may encourage the vacuum packaging of fatty fish and this, at the same time, would prevent freezer burn. Given the uncertainty as to whether temperatures in display freezers are sufficiently low and constant, this may well lengthen the shelf-life of fatty fish. But it is not at all clear as yet what success may be reached in any particular case. Regarding this whole set of problems, Banks (1965) writes: "However, it has been observed that the complicated series of autolytic reactions that go on at chill temperatures and which, with cod, can lead to the formation of hypoxanthine in the flesh, can proceed in frozen herrings in the absence of oxygen. In considering the origin of 'off' flavours in frozen fish, therefore, account must be taken of changes that can be attributed to oxidation as a result of attack by atmospheric oxygen, and also of other oxidative reactions involving such components as trimethylamine oxide, together with reactions of an autolytic nature not normally requiring aerobic conditions."

Vacuum packaging

Vacuum packaging is essential in the case of boil-in-the-package pouches which are made of polyester film plus PE, or polyamide film plus PE since otherwise a high pressure would be generated in the closed pouch during the heating process. However, in the case of fish, there does not seem to be much economic future in this type of package. Cellophane plus PE vacuum packages have proved their worth for frozen kippers. For reasons of toxicological safety and also to minimize spoilage in distribution, pre-packaged smoked fish is being increasingly transferred from the cooler chain to the freezer chain. This is in line with the general trend of using freezing operations not only to ensure a long shelf-life but also to simplify distribution.

Glazing of large fish

Large fish are usually glazed in order to avoid weight loss and freezer burn. As long as the glazing is free from cracks, it is virtually air-tight. But in examining tuna stored under these conditions, Masamichi Bito (1964, 1965) came up against the following problem: "The discoloration by the oxidative change of myoglobin (Fe^{2+}) into metmyoglobin (Fe^{3+}) became considerable in tuna stored at −20°C (−4°F) within two months. The discoloration in the inner layer of meat was more considerable than on the surface. Such a phenomenon was not observed on samples stored at −35°C (−31°F) as the inner layer of these samples retained its original color (while the surface was more or less discolored)." The fact that at −20°C (−4°F) the discolouration is stronger in the inner layers is the result of the oxygen partial pressure, which depends not only on the activation energy of the oxygen diffusing into the flesh, but also on the oxygen consumption in the flesh. It does not seem impossible to control these phenomena satisfactorily by a suitable gas composition and oxygen permeability of the package.

SUMMARY AND CONCLUSIONS

The present trend seems to be that frozen fish will be preferred to chilled fish because freezing simplifies distribution and marketing. Much research has been done on protein denaturation which causes toughness to a high degree in frozen storage (Cowie and Little, 1967; Love, 1962; Olley and Duncan, 1965; Ackman, 1967). This toughening is dependent on the variety of fish, season, pH value and on the degree of hydrolyses of phospholipids, as well as the time and temperature of storage. While this problem is not yet solved, much less attention has been given to investigations on the oxidative changes which may lead to staleness. In all cases where oxidative changes are the limiting factor, the package should also be light-proof. Where freezer burn is the limiting factor, tightly-fitting packages (skinpacks) should be used. For these, a small opening by which air may escape during the shrinkage operation can be tolerated and will be necessary if the package is not evacuated prior to shrinking. In both these cases suitable packages must be combined with low storage temperatures and a reduced turnover time. At present, quality of frozen fish stands to gain far less from new plastics than from technological improvements in freezing operations aboard ship. The freezing process needs revising, especially to find some substitute for block freezing aboard ship. Block freezing, in combination with subsequent sawing into portions results in the occurrence of small pieces and the product is satisfactory only to the unsophisticated consumer. Therefore, the development of a process by which consumer packages consisting of whole fillets can be produced on board ship is necessary.

With regard to fatty fish, more attention should be paid to research and economical designing of vacuum-packaging because this process will not only prevent freezer burn but will also reduce oxidative changes. The latter is of importance for two different reasons: turnover time from the time of freezing on the ship until the product is sold from a display freezer is usually quite long and the magnitude of temperature fluctuations, as well as the residence time in the display freezer is often very high. In Sweden, regulations have been proposed to take these facts into account by calculating and marking the date of expiration (Anon., 1967). Aside from the indoctrination of wholesalers towards shorter storage times (in Sweden, two months at the most), the turnover times from date of catching are, in Europe, generally excessive from the point of view of quality hazards—the most important measure would be the reduction of residence times in display freezers. This will depend on the degree to which the principle "first in, first out" can be maintained. Since display freezers are frequently crammed, shoppers prefer packs from the lower layers; the rummaging disturbs the order and furthers the appearance of freezer burn and other quality deteriorations. Date-

marking of packages can prevent old supplies from being left around, but it cannot prevent rummaging with all its drawbacks. It may, therefore, be useful to develop automatic frozen fish vending equipment.

This paper does not claim to be a complete survey since conditions vary in the world's different major fishing grounds. Nevertheless, it may safely be stated that, however perfect a consumer package may look, the packaging of frozen fish still poses a great many technical, economic and scientific problems. It would be rewarding for an international meeting to provide an opportunity for the exchange of information on the actual turnover time and temperature relationship observed in particular cases, on costs, on experiences with various packaging methods and machines and, finally, on possible improvements in the distribution chain.

References

ACKMAN, R G 1967 The influence of lipids on fish quality. *J. Fd. Technol.*, **2**, 169–181.

ANON 1958 Haltbarmachung tafelfertiger Matjesfilets. *Inform. Fischw.*, **5**, 126.

ANON 1964 Recommandations pour la préparation et la distribution des aliments congelés. *Annexe Bull. int. Inst. Réfrig.*, p. 114.

ANON 1967 *Food Technology in Australia*, **19**, 403.

BANKS, A 1965 Technological problems in the control of deteriorative changes in frozen fish requiring more knowledge from fundamental research. In *The Technology of Fish Utilization*, ed. R. Kreuzer, pp. 89–91. Fishing News (Books) Ltd., London.

BITO, M 1964 Studies on the retention of meat color of frozen tuna. *Bull. Jap. Soc. scient. Fish.*, **30**, 847; and (1965) **31**, 534, 540.

BRAMSNAES, F and SØRENSON, H C 1960 Vacuum-packed frozen fatty fish. *Annex 1960–3 Bull. int. Inst. Réfrig.*, pp. 281–296.

COWIE, W P and LITTLE, W T 1967 The relation between the toughness of cod stored at - 7°C and −14°C, its muscle protein solubility and pH. *J. Fd Technol.*, **2**, 217–222.

HEISS, R 1951 Über die Vermeidung von Austrocknungsverlusten bei der Gefrierlagerung. *Kältetechnik*, **3**, 248–252.

HEISS, R. 1963 Untersuchungen über die an Gefrierpackungen zu stellenden Anforderungen. *Verpack.-Rdsch., Frankf. (tech.-wiss.)*, **14**, 17–24, 43–49.

KIERMEIER, F, HEISS, R and KAESS, G 1944 *Beiträge zur Vorratstechnik von Lebensmitteln*, p. 86. Theodor Steinkopff-Verlag, Dresden and Leipzig.

LOVE, R M 1962 The effect of freezing on fish muscle. In *Recent Advances in Food Science*, **1**, pp. 147–157. Butterworths, London.

OLLEY, J and DUNCAN, W R H 1965 Lipids and protein denaturation in fish muscle. *J. Sci. Fd Agric.*, **16**, 99–104.

Transport of Frozen Fish

by M. A. Foley

Transport of frozen fish

The primary principle in the transport of frozen fish is to move the fish from the processing establishment to the consumer, without loss of the quality preserved by freezing. This transport phase has long been a weak link in the cold chain of the fishing industry, not because of poor refrigeration equipment, poor insulation or poor construction but because the refrigerating medium, either cold air or gas, has not intercepted the heat passing from the exterior of the vehicle to the product. Furthermore, on loading and discharge there is usually a temperature rise in the product which could be avoided or minimized by improved design of handling facilities in refrigerated storages.

At present, small quantities of frozen fish are transported by aircraft. An increase in such traffic will come only with the provision of adequate refrigerated storage at airfields. The transport of fresh fish by air is perhaps more logical and economical than is the movement of frozen fish by this means.

Product temperatures of frozen fish aboard ship are felt to be adequate, although handling practices to, at and from the dockside should be improved. Apparently few surveys have been conducted to determine the temperature of frozen fish from processing storage, through ocean transport, to distribution storage.

At present, refrigeration for the railway transport of most frozen fish is provided by the ice-salt system. In certain countries this will be replaced, during the next decade, by mechanical and liquid gas systems providing lower temperatures.

The use of containers and highway vehicles on flat-cars is providing necessary transport flexibility.

It would appear the refrigerated highway vehicles transport most of the frozen fish and that product temperatures, in many cases, are less than ideal.

In-city or distribution transport of frozen fish has its own peculiar insufficiencies which are difficult to overcome but which can be lessened considerably.

The transport of frozen fish in special containers, which are refrigerated from a central system or which have their own integral refrigeration system, is increasing as this transport concept develops. It offers decided economic and quality advantages if the fishing industry designs storages and handling facilities which are complimentary.

In general fish quality during transport is being better maintained with the application of improved handling practices and the lowering of temperatures. It is anticipated that, while more frozen fish will be produced and moved to market in many countries, there will be a parallel increase in the transport of fresh fish in other countries where techniques are developing to lengthen shelf life.

Proven technical development, if applied intelligently, can maintain frozen fish quality during transport and gain customers.

Transport du poisson congelé

Lorsqu'on transporte du poisson congelé l'essentiel est de le faire parvenir de l'usine de transformation aux consommateurs sans qu'il perde la qualité que préserve la congélation. Depuis longtemps, c'est le transport qui est le maillon le plus faible de la chaîne du froid dans l'industrie halieutique, non que le matériel de réfrigération, l'isolement ou la construction laissent à désirer, mais parce que l'agent frigorigène, air ou gaz froid, n'intercepte pas la chaleur, qui pénètre dans le véhicule et atteint le poisson. De plus, le produit subit généralement au chargement et au déchargement une hausse de température qui pourrait être évitée ou du moins réduite si l'on améliorait les installations de manutention dans les entrepôts frigorifiques.

Jusqu'à présent le tonnage de poisson congelé transporté par voie aérienne reste faible; il ne pourra s'accroître que si les aéroports sont dotés d'entrepôts frigorifiques appropriés. Ce mode de transport semble plus rationnel et économique pour le poisson frais que pour le poisson congelé.

A bord, la température du poisson congelé est satisfaisante, mais des progrès sont nécessaires dans la manutention à quai et pendant les transbordements. Il semble que peu d'études aient été consacrées à la température du poisson congelé, depuis l'entreposage à l'usine de congélation, jusqu'aux entrepôts de distribution, en passant par le transport maritime.

A l'heure actuelle, c'est le plus souvent par de la glace additionnée de sel qu'est assurée la réfrigeration pendant le transport du poisson congelé par voie ferrée. Dans certains pays, cette méthode sera remplacée dans les dix prochaines années par des dispositifs mécaniques ou à gaz liquides permettant d'assurer des températures plus basses.

Le chargement de containers ou de véhicules routiers sur des wagons plats assure la souplesse nécessaire dans les transports.

Il semble que l'essentiel du poisson congelé soit transporté par véhicules réfrigérants et que la température du produit laisse souvent à désirer.

Le transport en ville et au stade de la distribution présente des problèmes particuliers difficiles à éliminer mais dont les effets peuvent être considérablement réduits.

Le transport du poisson congelé dans des containers spéciaux réfrigérés à partir d'un système central, ou par un dispositif autonome, se développe: ce mode de transport, de plus en plus répandu, offre de nets avantages du point de vue de la rentabilité et de la qualité pourvu que l'industrie halieutique s'équipe des entrepôts et moyens de manutention complémentaires.

D'une façon générale, c'est en améliorant les méthodes de manutention et en abaissant les températures que l'on contribue le mieux à maintenir la qualité du poisson durant le transport. Tandis que la production, le transport et la distribution du poisson congelé se développeront dans de nombreux pays, le transport du poisson frais marquera sans doute des progrès parallèles dans d'autres pays où l'on met au point des techniques permettant de prolonger la durée de conservation.

Une application intelligente des progrès techniques éprouvés permettra d'assurer le maintien de la qualité du poisson congelé pendant le transport et de gagner une clientèle plus nombreuse.

Transporte de pescado congelado

El principio fundamental del transporte del pescado congelado consiste en llevarlo desde el establecimiento de elaboración hasta el consumidor sin que pierda la calidad que conserva la congelación. Esta fase del transporte ha sido el eslabón débil en la cadena del frío de la industria pesquera, no tanto porque no fueran buenos el equipo de refrigeración, el aislamiento o la construcción, sino porque el medio refrigerante, bien aire frío o gas, no ha conseguido impedir que el calor exterior penetre en el vehículo y llegue hasta el producto. Además, al cargar y descargar, aumenta casi siempre la temperatura del producto, lo que puede evitarse o reducirse al mínimo mejorando los medios de manipulación en los frigoríficos.

En la actualidad se transportan en avión pequeñas cantidades de pescado congelado, que no aumentarán hasta que se dote a los aeródromos de suficientes frigoríficos. Posiblemente es más lógico y económico transportar en avión pescado fresco que pescado congelado.

Se considera que son adecuadas las temperaturas del pescado congelado a bordo, aunque deberían mejorarse los sistemas de manipulación desde el barco hasta el muelle, en el muelle y de éste al consumidor. Se han hecho pocos estudios para determinar la temperatura del pescado congelado desde el frigorífico del establecimiento de elaboraración, durante el transporte marítimo, hasta el almacén de distribución.

En la actualidad, casi todo el pescado congelado que se transporta por ferrocarril se refrigera mediante el sistema de hielo-sal. En algunos países durante la próxima década será sustituido por sistemas mecánicos y de gas líquido que permiten mantener temperaturas más bajas. Da al transporte la necesaria flexibilidad el empleo de grandes cajones cerrados y de vagones de plataforma en los que viaja el camión.

Casi todo el pescado congelado se transporta en camiones refrigerados y en muchos casos las temperaturas del producto dejan mucho que desear.

El reparto urbano de pescado congelado presenta defectos característicos difíciles de suprimir pero que pueden reducirse considerablemente.

El transporte de pescado congelado en envases especiales que se refrigeran desde un sistema central o que tienen su propio sistema de refrigeración, aumenta al propagarse este concepto del transporte. Ofrece importantes ventajas económicas y de calidad, si la industria pesquera proyecta frigoríficos y medios de manipulación que sean complementarios.

En general, la calidad del pescado congelado se mantiene mejor durante el transporte gracias a la aplicación de sistemas de manipulación mejorados y a la reducción de las temperaturas. Se anticipa que si bien en muchos países se producirá más pescado congelado que se enviará al mercado, ocurrirá un incremento análogo en el transporte de pescado fresco en otros países, en los que se perfeccionan técnicas para prolongar la duración en almacén.

Los progresos técnicos bien ensayados, si se aplican científicamente, pueden mantener la calidad del pescado congelado durante el transporte y aumentar el número de consumidores.

IT is perhaps worthwhile at this stage to reflect for a moment as to why we freeze fish and then transport it in this frozen condition to the consumer. While it is true that a number of engineering problems must be recognized and solved, the solutions are not goals or ends in themselves. The goal in transport must be to move fish in a manner that will preserve the quality which is locked-in or preserved by freezing. Storage is necessary, of course, at various stages in the process to cope with the vagaries of supply, nature and humans. In brief, the consumer must be assured of a supply of fish products handled in a way that will minimize costs and preserve inherent quality. This is academic perhaps, but at times it is forgotten in the pre-occupation with solving technical problems.

The transport of the frozen product, unlike the catching and processing functions, is not at all unique to the fishing industry. Frozen fish generally constitutes only a small fraction of the total frozen food moved from the processor to the consumer. What is unique is its perishability and the relatively low constant temperature, which is necessary during transportation to prevent loss of quality, as shown by Dyer *et al.* (1957).

Transport is usually not a function of the fishing industry, except in some vertically integrated companies, but is provided by commercial carriers—railways, truckers, shipping companies and airlines—which are not always conversant with, nor appreciative of, the requirements of the product. Economy in transport, handling practices on loading and at discharge, equipment used, and the number of off-loading points all tend to cast their particular shadow on the quality picture during product movement. The vast number of units with varying degrees of efficiency in design, operation and maintenance, which are moving frozen fish to all points of the compass, over varying distances, create inherently difficult problems in the assessment and regulation of such traffic. The development, application and enforcement of optimum practices in the industry commenced in the shore processing plant, probably because it is a static installation and in-plant storage and product temperatures are more easily obtained and maintained. Storage capacity or pay-load is less critical than in the transport phase where maximum cargo must be carried with minimum cost. Design considerations are markedly different. Storages are not subjected to continuous winds of 80 to 95 km/h (50 to 60 mph), temperatures of 32°C (90°F) on all six external surfaces, a maximum permissible wall thickness of 10 to 15 cm (4 to 6 in), a very high ratio of wall surface to quantity of product, little or no space for air circulation around the product and a warming of the room to ambient temperature before the doors are closed and the refrigeration system reactivated. If it is felt that the case is overstated, imagine a refrigerated truck or train travelling at 80 km/h (50 mph) with a wind of 50 km/h (30 mph) at 32°C (90°F) blowing at right angles to the direction of travel.

It is generally recommended that frozen fish be stored in the range of −23° to −29°C (−10° to −20°F) and the industry is striving to meet this requirement as well as to freeze under complementary optimum conditions. Ideally, it would be desirable to transport the frozen product at storage temperature and to move the fish to and from the vehicle in a manner which would preclude, or at least minimize, the usual rise in product temperature. Such a specification or recommendation would seem entirely unrealistic and impracticable at first glance and, during transport, it undoubtedly is. However, does this necessarily apply to the loading and unloading functions? Are present methods wholly realistic where warmly clad workers move the frozen product from storage at −29°C (−20°F) through temperatures of 27°C (80°F) to the vehicle which, with open doors, is rapidly approaching ambient temperature under the influence of sun and wind? Why not load and unload the vehicle in a room or area with at least a measure of temperature control? Why not bring the railway wagon, van, truck or trailer into a storage anteroom rather than position it outside at a loading dock? Ocean cargoes admittedly present additional difficulties but in most cases vessel loading and discharge can be improved.

In the transport of frozen fish, as in so many other areas, there is a tendency to focus on a particular or specific aspect of the problem and seldom to view panoramically. The construction, the type and thickness of insulation, the choice of refrigeration equipment, whether or not to use liquified gas or a mechanical system, the pre-cooling of the vehicle and other factors are all important facets of the problem which must be considered, in context, as part of the whole—which is the efficient transport of high quality frozen fish to the consumer. Conversely, there frequently exists the tendency to generalize and apply the findings or experience of one area to another without due regard for obvious differences. The refrigerated vehicle which is suitable for transporting fish in Spain may not be suitable for use in Canada where distances are great and where the temperature spread from summer to winter can be 83degC (150degF). The vehicle in Spain probably requires refrigerative capacity for both fresh and frozen fish whereas the one in Canada must be provided with a source of heat to maintain fresh fish at 0°C (32°F) with an ambient temperature of −45.5°C (−50°F). A liquid nitrogen system is not the complete answer in such an instance in Canada, although it may be in Spain. A relatively small, densely-populated country, such as England, probably can develop quite specialized equipment whereas Canada requires more versatility. Furthermore, there is quite often a pre-occupation with average product temperatures or, which is much worse, air temperatures measured at the evaporator outlet or above the load, rather than with the worst or highest product temperature. The consumer is not at all interested in averages but in the quality of the fish on his plate.

To continue, it would appear that there is a marked tendency to design a mobile refrigerated storage, having due regard for pay-load capacity, type and thickness of insulation and method of refrigerating, and then to test the empty vehicle to determine its overall efficiency. This is most workmanlike and useful but really does not present a complete picture unless testing is conducted under operating conditions with a full cargo loaded as in commercial practice. It is an extremely poor vehicle that will not maintain optimum conditions of temperature when empty, even at very high ambient temperatures. Empty vehicles are quite often tested when new, before

Fig 1. Refrigerated container on highway flat-bed trailer

openings in seams have developed in the external skin due to "working", before insulation has become moisture-laden and before there has been mechanical damage to the insulation due to one block rubbing against another —in fact, before the vehicle becomes operational. Such testing is undeniably most useful in determining effectiveness of insulation, capacity of refrigeration system and tightness of the skin, but it is recommended that the final phase of testing be carried out under full-load conditions and that vehicles be tested periodically, perhaps every two years. Testing and rectification of defects may be far less expensive than paying claims on cargoes delivered at higher than permissible temperatures.

The crux of the matter and the main design consideration is the absolute requirement to provide refrigeration where it is needed—surrounding the load—by such media as low temperature air, liquified gas or eutectic plates. Arrows on design drawings indicating hoped-for paths of circulation are not sufficient. Adequate circulation cannot be assured merely by installing ribbed interior side walls and extruded aluminium troughed-type floors. The refrigerated air must have positive direction and force sufficient to encompass the entire cargo and to pick up heat before it reaches the cargo. It is recommended that, in refrigerated storages, a space of at least 7 to 10 cm (3 to 4 in) be provided between the product and interior walls, yet 2 cm ($\frac{3}{4}$ in) spaces are quite common in refrigerated trailers as are floors with slots or troughs about 2.5 cm (1 in) in cross section. In the provision of necessary circulation, refrigeration systems blowing over the top of the load are somewhat akin to a fire-place inasmuch as one side remains cold while the other gets warm. Storage rooms are jacketed or wall and ceiling surfaces are covered with refrigeration grids but in transport there is quite often an abiding faith that the heat passing through walls will, in some manner, not reach the product. Refrigeration coils or plates between the load and the insulation would provide the necessary effective block to ingress of heat but such systems on all six surfaces tend to be heavy, bulky and expensive. The jacket, semi-jacket, cold wall or envelope system has proven to be satisfactory and, despite presenting some minor difficulties in construction, is workable in commercial application. A properly designed and installed jacket system will provide assured protection of the cargo and is not prone to insufficiencies arising from improper loading procedures since the product can be placed directly on the floor and against walls or bulkheads. A full envelope system will maintain high humidities within the cargo space and this is important in the transport of unpackaged frozen or fresh fish.

The principles of the jacket or envelope system for refrigerated storage are too well known to require elaboration. It perhaps is sufficient to note that inherent difficulties in the design and construction of transport vehicles are minimized with such a system. The leakage of heat and air through exterior skin and insulation is picked up or trapped by the circulating refrigerating medium before it reaches the product. The effects of thermal bridges, inadequate insulation over structural members and other insufficiencies are transferred to the refrigeration system rather than to the product.

The following brief reviews are attempts to delineate and describe current practice in the field of transport of frozen fish, as well as to predict probable developments and progress in transportation.

Generally, it is expected that storage temperatures in both static and mobile installations will be lowered; control will be more precise and temperature fluctuations within the product will be minimized; cargo loading and discharge operations will be carried out without exposure of the product to the usual varying air temperatures; handling will be greatly lessened; transport vehicles will be more versatile; and, most important, there will be a lessening of quality deterioration in the transport phase of the operation—long a weak link in the cold chain. There will be considerable technological development in the field of transport but with it there must be careful attention to perspective, if progress is to be realized. Development must be measured against economy, against equipment reliability, against weight and against product quality.

AIR TRANSPORT

It would appear that little frozen fish is at present moved or transported by aircraft although traffic in fresh fish, especially the more exotic and expensive species, is growing rather rapidly. Indeed, aircraft and frozen fish may not be logically compatible if speed in transit is equated to the purpose of freezing. It is perhaps far more logical and profitable to use air freight for fresh fish, although it undoubtedly has a place in the movement of frozen fish in specific cases.

The successful movement of fish, either fresh or frozen, by air will require the development of suitably insulated lightweight waterproof one-way boxes, holding perhaps 35 kg (75 to 80 lb), for use with or without containers. Refrigerated storages at both 0°C (32°F) and −29°C (−20°F) will be required at airfields. The boxes, without containers, could be used for fresh fish on relatively short flights of one or two hours' duration. The same boxes in containers would be used for frozen fish or for fresh fish on long distance flights. The boxes or cartons might be of impregnated corrugated cardboard, well insulated and fitted with telescopic-type lids.

The product, if fresh, would be pre-cooled to about −1° to −2°C (+30° to +28°F), placed in the insulated box or carton in the refrigerated storage and moved to the airfield in a suitable vehicle and stored in the 0°C (32°F) room until flight time. On arrival at the airfield of destination, the procedure would be reversed. Procedures

for frozen fish would be similar except that the cartons would be placed in a container, perhaps with dry ice to provide necessary refrigeration on long flights or where cargo must be transhipped.

In jet transport it may be possible to take advantage of the low temperatures at high altitudes to provide necessary refrigeration for both fresh and frozen products.

A number of trial air shipments of frozen fish have been made using heavily insulated containers refrigerated with liquid nitrogen. In one shipment the containers of frozen fish were charged with sufficient nitrogen at the point of origin to provide refrigeration for the flight which entailed stopovers. At first glance, such a system does not appear wholly realistic especially as the product is lowered to approximately −196°C (−320°F) and the container must be insulated for this temperature. The absence of moving equipment, valves, external nitrogen containers and the need to recharge, may outweigh the disadvantages, in some cases.

Air lines are generally finding freight a very profitable proposition and are forecasting that more fish will travel by air—probably fresh fish in the initial stages and later, as methods and techniques are developed, frozen fish.

MARINE TRANSPORT

At present frozen fish is held in low temperature refrigerated storage aboard catching or factory ships, as well as in ships designed wholly or in part for the transport of products frozen ashore. A few refrigerated vessels have been designed specifically for the movement of frozen fish to market.

Insulated holds and refrigeration equipment are generally similar to those of shore installations, with application or construction in conformity with the specifications and recommendations of the classification societies.

Temperatures in holds are generally maintained by a combination of deckhead, bulkhead and ship's side cooling coils or grids. Some vessels utilize central evaporators with a system of fans and ducts to provide air distribution. Jacket or envelope systems seemingly have been used infrequently in marine installations.

CATCHING AND FACTORY SHIPS

Fish caught, efficiently processed, frozen and stored in the same ship is undoubtedly of the highest quality. This link in the cold chain would appear especially strong. Any subsequent deterioration results from handling ashore, during transportation to storage and to market or in the retail outlets. If, however, the fish is frozen aboard the vessel in the unfilleted stage, it is perhaps subjected to processes that, to some extent, tend to lessen the high initial quality.

The question of whether to freeze fillets or round fish is, to a considerable extent, unresolved as is the whole concept of freezing at sea by nations which are close to productive fishing grounds.

It would seem probable that the rising cost of catching vessels and the increasing competition for fish stocks will necessitate a closer examination of the economics of freezing at sea as a means of maximizing return on invested capital. Whatever the future holds, it would seem abundantly clear that more attention must be given to handling arrangements and to the temperature environment of the fish aboard ship. Exclusive of physiological changes in the living fish prior to capture, the quality is predetermined, to a considerable extent, aboard the vessel and the magnitude of loss of quality is determined by factors such as temperature, wind and sun and time of exposure.

REFRIGERATED CARGO VESSELS

Difficulties in the transport of frozen fish by ship lie usually in handling, both on loading and at discharge. The situation where the ship berths alongside refrigerated storages for both loading and discharge is ideal but probably not frequently encountered. For the most part the product suffers from inadequacies during loading into a truck or van, unloading at dockside, hoisting aboard and stowage in the holds, all of which may be aggravated by coffee breaks, lunch and the usual traffic snarls on the way to the ship and at dockside. Similar difficulties and problems are encountered on discharge.

Designers and shipping companies have been apparently both far-seeing and understanding, as most refrigerated ships appear to have sufficient refrigeration capacity to lower product temperature during passage.

Fig 2. Refrigerated container in ship's hold

Perhaps this is a built-in safety factor to offset loss of efficiency in insulation and equipment with age. It would be interesting, however, to obtain product temperatures from storage to storage. It is to be hoped that these would not be too disillusioning.

Present trends in ocean shipping would appear to be toward the use of containers for most general cargoes. The required ships and "container-ports" are being built to lower transhipping and handling costs and to reduce pilferage, breakage and damage. Containers with their own refrigeration systems are at present in use in ships without refrigerated holds, as are containers employing the "one-shot" nitrogen system. Truck trailers with demountable wheels are being transported aboard ship with obvious economies and efficiencies.

Shipping companies and several countries are committed to the containerization principle and it would therefore seem likely that more fish will be moved in this manner in the coming years.

RAIL TRANSPORTATION

The ice-salt bunker car or wagon which came into being at the turn of the century still accounts for most of the refrigerated railway rolling stock. While there have been improvements in construction, insulation and air circulation, the basic refrigeration system remains largely unchanged, despite the fact that elaborate ice storages and re-icing procedures are required on long hauls and that product temperatures can seldom be maintained below −12°C (+10°F). Such cars, while generally adequate for unfrozen products, usually do not provide accurate temperature control.

Mechanically refrigerated equipment came into use about 1950, accomplished for the most part by installing mechanical equipment in ice bunker cars. Since that time cars, providing excellent temperature environments for frozen products, have been designed and constructed utilizing the jacket principle. In Canada the railroads are forecasting a total disappearance of the ice-salt bunker car within the next five years. Low temperature cars are of new construction and those for fresh products are either of new construction or modified ice-salt bunker cars. It is planned to employ diesel-electric compressor systems with sufficient fuel for 10 days' operation under full-load conditions.

The low temperature cars are capable of maintaining any temperature in the range from 24°C (75°F) to below −18°C (0°F) and of changing automatically from cooling to heating as the need to cope with ambient temperature conditions requires.

Liquid nitrogen, liquid and solid carbon dioxide and liquid air refrigerants have not been in common usage by North American railways, although there have been many trials, experiments and a number of commercial installations. One such trial in Canada used liquid nitrogen to provide refrigeration for some 27,000 kg (60,000 lb) of fruit and vegetables on a summer haul from Vancouver to Toronto, a distance of about 4,800 km (3,000 miles) over a period of six days. The average temperature of the load on arrival was −47°C (−53°F) with a hot-spot temperature of −29°C (−20°F) and a cold-spot temperature of −58°C (−72°F). The produce, loaded at −21°C (−5°F), was reduced to −65°C (−85°F) in 2 h without the car having been pre-cooled. The car was charged with 10,000 l of liquid nitrogen over a period of 2 h, after the loading of the produce. A load of frozen fish was transported to Montreal from Vancouver with similar temperature results.

The climatic conditions in Canada as mentioned previously favour the use of mechanical systems capable of providing both cooling and heating with automatic control. The use of chemical refrigerants requires an additional heating system which adds to the cost and is considered troublesome. The use of such systems requires charging stations or depots similar to the ice-salt systems which the railways are interested in eliminating.

Despite the advances and developments by railroads in North America, most of the frozen foods over the past decade have been moved by road transport, perhaps because it responded more quickly to modern demands and could carry directly from storage to storage thereby minimizing handling. The "piggyback" service—trailers on flat cars—has done much to provide similar service and to improve the position of the railways, perhaps by lessening the utilization of refrigerated railway cars. This may not be the case in Canada where distances are great and the population is concentrated in a few major centres.

The movement of frozen fish by railways is at better temperatures than was the case a few years ago. This will continue to improve as older equipment is modified or is retired from service. As railways are tied to the rails, they have little or no lateral movement capability and, where this is necessary, must resort to "piggyback" or container systems. The "piggyback" system allows railways, which are developing their own road transport fleets in many instances, to have or to provide the best of both worlds. Container railway traffic is developing through the use of self-contained units and with diesel electric power units serving four or five containers, all of which are carried on a flat car. Such containers, with complementary storage design, could be loaded, transported and unloaded so as to maintain optimum product temperature conditions. The use of high-cost equipment for the return journey or backhaul will probably always present economic difficulties except in the few cases where frozen products are carried in both directions. The situation can be ameliorated somewhat with versatile equipment that can provide accurate and adequate product temperatures in the range of +24° to −21°C (+75° to −5°F). However, the capital investment for equipment is relatively high and the transport of heat-insensitive cargoes, while assisting economically, does little to offset refrigeration and insulation depreciation charges.

ROAD TRANSPORTATION

It is estimated that, in 1963, about 85 per cent of approximately 8.5 million tons of frozen foods transported in North America was via highway. Railway and ship transport accounted for most of the balance as the airlines seemingly carried less than 500 t. In 1965, frozen fish traffic in Canada was at the level of about 250,000 t with fresh fish at about 125,000 t. Preliminary world statistics for 1965 indicate that some 5.75 million tons of fish were frozen, an increase of slightly over 1 per cent from the preceding year. Statistics on a world basis for the transport of frozen fish are elusive but one is inclined to feel that highway transport accounts for a high proportion of it. Indeed, there is probably little frozen fish that is not handled by road vehicle in one or another stage of transport.

Despite the fact that highway vehicles carry such large quantities of frozen products and the great number of investigations and papers on the subject, there exists considerable doubt as to the efficiency of many of the units in the transport of frozen foods at temperatures of −18°C (0°F) or below. It would seem that, for every paper dealing with product temperatures measured under actual operating conditions, there are at least 200 papers on various aspects of transport refrigeration systems, vehicle construction, insulation and operating costs. We tend to assume that "all is right with the world" because construction is good, insulation is sufficient and a refrigeration system has been installed. Such thoughts are given further credence because the vehicle thermostat is set at −23°C (−10°F) and the remote reading thermo-

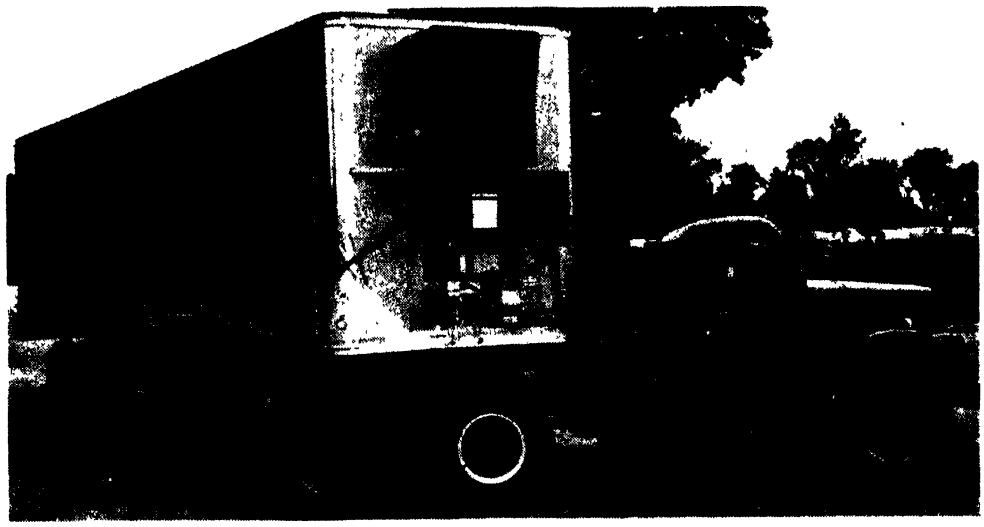


Fig 3. Refrigerated highway test trailer showing temperature recorder

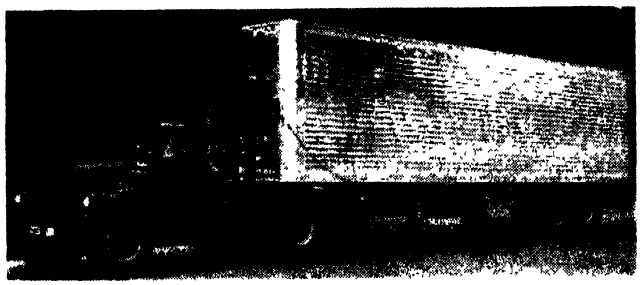


Fig 4. Refrigerated highway test trailer

meter indicates that this temperature is being maintained while, in fact, some of the load may be thawing.

Some doubts arose in Canada as to actual temperatures during transit and, as a result, surveys of 58 loads of frozen fish were carried out in 1959 (Lentz and Rooke, 1960). Briefly, while loading temperatures were below −18°C (0°F) in most instances, at destination temperatures had risen to above −9°C (+15°F) in 80 per cent of the loads, above −6.5°C (+20°F) in 50 per cent and above −4°C (+25°F) in 25 per cent of the loads. Some localized thawing occurred in one of every 10 loads.

A later investigation of temperatures in frozen poultry, fruit and vegetables, in 37 loads, showed somewhat worse conditions (Lentz and Rooke, 1961). None of the trailer units held temperatures below −9°C (+15°F) during the warm months, only one in five maintained temperatures below −6.5°C (+20°F) and almost half had temperatures of −4°C (+25°F) or higher.

Generally, the trailers were in good condition. Most of them had 7 to 10 cm (3 to 4 in) of insulation in walls and roof and 10 to 15 cm (4 to 6 in) in the floor. In addition to floor channels 2.5 cm (1 in) deep and the provision of 2 cm ($\frac{3}{4}$ in) spaces along the walls, pallets provided a 5 to 10 cm (2 to 4 in) air space.

The high temperatures recorded indicated the need to determine the reason for the poor results. A new semi-trailer was obtained and tested under empty, loaded, stationary and road conditions (Lentz, Muir and Foley, 1964). Results verified the findings of the earlier surveys. Product temperatures could not be maintained at the −18°C (0°F) level, even with the refrigeration system operating continually.

A plywood false floor and wall system was installed to provide air circulation all around the load and the trailer was tested again under similar conditions. Results showed a marked difference. Maximum product temperature was reduced from 0°C (32°F) in initial testing to −18°C (−0.6°F). The average temperature was lowered

Fig 5. Highway test trailer showing temporary jacketing

from 8.7° to −20.6°C (+16.4° to −5.5°F). The maximum temperature difference between different points in the load was lowered from 18 to 4.5 degC (32.5 to 8.2 degF).

A subsequent study of a liquid nitrogen refrigerated trailer with foamed-in-place polyurethane insulation showed product temperatures similar to those obtained with the mechanical systems without positive air circulation on all sides of the load (Lentz, Muir and Foley, 1964). It is therefore suggested that, no matter what refrigeration system is employed, the load must be surrounded on all sides by sufficient refrigeration and its application must be positive.

After the completion of surveys and tests, meetings were held with the various branches of the Canadian Trucking Association from coast to coast, to discuss equipment insufficiencies, indicate corrective action and the general technology and philosophy of refrigerated transport. Since that time (1965) a number of trailers embodying the jacket principle have been built, are operating efficiently and are maintaining product temperatures of −18°C (0°F).

At the request of the Canadian Trucking Association, a further survey was carried out this summer in which monitoring of loading and discharge product temperatures was conducted on 50 trips each of long-range hauls of about 4,800 km (3,000 miles), intermediate hauls of 1,600 to 2,400 km (1,000 to 1,500 miles) and short hauls of 160 to 800 km (100 to 500 miles). It will be some time before results can be assessed. It is hoped that there will be a significant improvement over the temperatures recorded in 1959, especially as requirements are becoming more stringent in the matter of product temperatures during transport.

IN-CITY DELIVERIES

Deliveries from distribution warehouses to shops, restaurants, hotels, etc., are made in trucks and vans with temperature-holding capabilities ranging from excellent to extremely poor, in units that are well-insulated and well-cooled, and in units which do not afford protection even from the sun. The only salvation of quality, in many cases, results from the fact that these trips are short, both as to time and distance. When this is not the case, much of the costly built-in quality is lost and, perhaps, potential customers as well.

The problems of long distance non-stop refrigerated transport are relatively easily solved but those of local multiple-stop deliveries are much more difficult, even with first-rate equipment—perhaps because the pattern of operation and the human element play a much larger role. Twenty or 30 deliveries require that the door be opened and closed at least that number of times. The driver must be both appreciative of requirements and dedicated to his job. Air interchange is minimized by partitioned load space but this increases capital costs and is not a completely practicable solution. Liquid nitrogen and carbon dioxide with their quick temperature pull-down characteristics offer decided advantages but their inhospitable atmospheres cause difficulties. This might be overcome by loading of boxes on a power-driven roller conveyor-type floor on a "first in, last out" basis. Another solution might be the packing of individual orders in low cost one-time insulated boxes in the distribution warehouse at storage temperature prior to loading into the pre-cooled truck.

It is most difficult to predict what will happen to highway transportation but, assuming that roads become no more traffic clogged than at present, it would seem likely that, in most countries, trucks will carry a high proportion of frozen products due to their relatively low capital costs and their versatility. With demountable wheels, trucks can become "containers" for marine transport and, with or without wheels, they can be moved by railways. Handling methods must be improved and open loading docks will probably disappear, giving way to special loading areas or bellows-type seals between the warehouse and the truck or trailer.

The situation with multiple-stop city deliveries is more difficult and probably can be most easily improved through better handling methods. The use of individual insulated containers for each delivery may be practicable, in combination with the low temperature liquid refrigerants or with plate coil-type evaporators on the floor and partially up the walls.

CONTAINERIZATION

This shipping concept, which decreases handling costs and preserves product quality, is developing rapidly for marine, railway, highway and air transport. Other advantages of container transport are a decrease in overall shipping costs, a decrease in insurance costs, a speed-up of delivery and a reduction of product damage

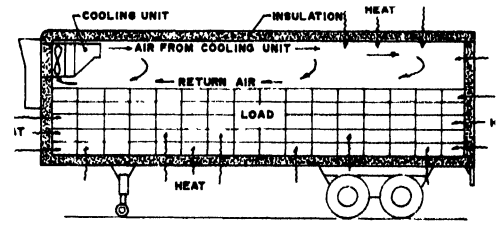


Fig 6(a). Schematic sketch illustrating air circulation and heat infiltration in a refrigerated trailer of conventional design

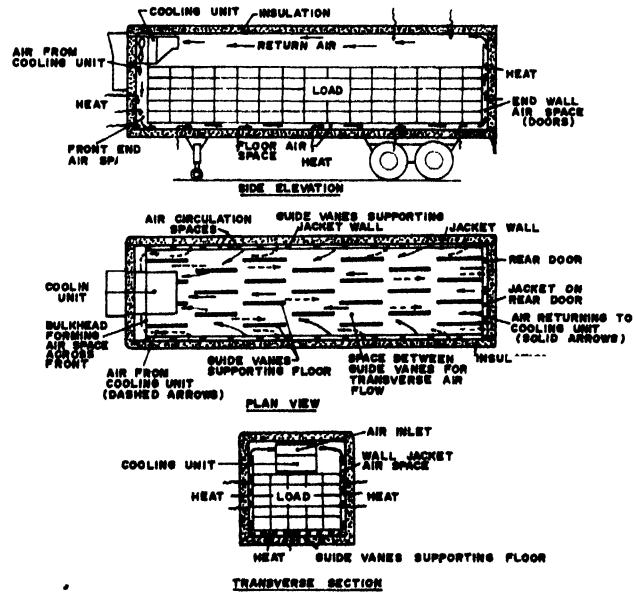


Fig 6(b). Schematic sketch illustrating air circulation and heat infiltration in a refrigerated trailer with a jacket air circulation system

and pilferage. There are, however, problems in the use of containers which must be solved. Labour difficulties are created as containers displace workers; containers must be maintained; capital investment in containers is high, especially for refrigerated units; handling equipment and practices must be attuned to container operations; and there must be a fair degree of standardization of container sizes which will require international co-operation. Container operations can successfully provide a degree of flexibility and versatility in all types of transport, although possibly less so in road transport.

It would appear that the use of containers for refrigerated cargoes will develop over the next decade as this concept in transportation gains acceptance and the necessary handling equipment is installed. Compact refrigeration systems utilizing chemical refrigerants fed from a central container will be required, as will mechanical systems designed for both air or liquid condenser cooling. Container design and construction embodying the use of the newer structural materials will be developed to both increase efficiency and to lower capital investment

CONCLUSION

Conditions and temperatures in the transport of frozen fishery products are improving, thereby strengthening the weakest link in the cold chain. Practices must be improved to remove or lessen the interminable delays in handling and also to lessen the time of exposure of the product to high temperatures.

Units for the transport of frozen fishery products must be designed and constructed to provide adequate and positive circulation around the load. While it is not suggested that the envelope-jacket-cold wall principle is the only way of assuring adequate refrigerant circulation, it is a system which will do so, is commercially practicable, offers many advantages and removes the possibility of inadequacies in loading.

There is no doubt that more and more frozen fish will be transported, especially within countries where distribution systems are developing and expanding. It would also seem that there will be a marked increase in the marketing and transport of fresh fish in many countries, due to improved temperature environments and handling practices aboard catching vessels, improved processing techniques ashore and extended shelf-life of the product due to advances in food technology such as in the field of irradiation.

Solutions to most of the problems in the refrigerated transport of frozen products, including fish, are known and have been set forth in the myriad of papers on the subject. What is now required is intelligent application and observation.

References

DYER, W J, FRASER, D I, ELLIS, D G and MACCULLUM, W A 1957 Influence of intermittent short storage periods at 15°F, as encountered during refrigeration car transportation, on the quality of frozen cod stored at 0°F. *J. Fish. Res. Bd Can.*, **14**, 627–635.

LENTZ, C P and ROOKE, E A 1960 Temperatures in frozen fish shipped by road in refrigerated trailers. *Can. Fd Ind.*, **31** (2), 26–28.

LENTZ, C P and ROOKE, E A 1961 Temperatures in frozen poultry, fruit and vegetables shipped by road in refrigerated trailers. *Food in Canada*, **21** (12), 38–41.

LENTZ, C P and ROOKE, E A 1966 Design of an air circulation system refrigerated trucks. *Can. Fd Ind.*, **37**(6), 32–35.

LENTZ, C. P., ROOKE, E. A. and FOLEY, M A 1961 Performance tests with a refrigerated trailer. *Food in Canada*, **21**(5), 24–28.

LENTZ, C P, MUIR, W E and FOLEY, M A 1964 Performance tests with a liquid nitrogen cooled trailer. *Can. Fd Ind.*, **35**(2), 54–57.

DISCUSSION

Bahr (Federal Republic of Germany): On 1st January 1968, a law will come into force in the Federal Republic of Germany which will introduce open dating of all deep frozen goods. After this date, all producers of deep-frozen fish have to show a date on all packages destined for consumption. They are allowed to choose between the date of production and the last date for consumption. This law, which covers other frozen foods, was brought about by the representatives of consumers in the Parliament of the Federal Republic. It was a decision in the field of public health policy. The fishing industry was against the date law. It argued that it would be better to leave the policy of dating to the field of free competition and that the offering of good quality to the housewives should remain the responsibility of the retailers. Indeed, there will be several problems with this regulation. Quality is perhaps more dependant on treatment in the cold chain than on the time factor. There is the possibility that the retailers' problems will increase when the consumer depends too much on the date instead of looking for the real quality. The future will show whether this date regulation will succeed in really improving quality control and in increasing the demand for frozen fish.

Little (U.K.): I would like to go on record regarding the dating of fish products. This Conference has concluded that fish batches are not homogenous and that they spoil at different rates depending on their intrinsic properties and treatment before storage. It is, therefore, impossible to see how a date would have any meaning. In any case, does the producer have to produce a quality rejection limit and what is this to be based on? Who can decide at present if a date on a packet is meaningful? In the state of our present knowledge it would appear that any dating on packets would be absolutely meaningless.

Kovacs (Federal Republic of Germany): In connection with Dr. Bahr's information concerning the forthcoming German regulation requiring dating of all frozen products, one should recall the discussion on quality deterioration at this Conference which showed that time alone, without considering storage conditions, has no meaning. Since he has no control over the product after it leaves his premises, it would be an injustice to request the manufacturer to guarantee its shelf life by declaring the time within which it must be used. Stating time of manufacture is also meaningless—an older product under good storage conditions may be in a better condition than a younger product under bad storage conditions. As a repre-

sentative of a consumers' organization I must say that this new law does a bad service to the consumer, by giving him a false security regarding the quality of the product he buys.

Merritt (U.K.): In an earlier Session (Part IV) Danielsen asked why the retail cabinets for frozen food operate at such high temperatures. On discussing the manufacture of cabinets on one occasion, a manufacturer pointed out to me that he had made a good cabinet with low temperature, but could not sell it at a profit, because it was relatively costly to manufacture and there was no demand for it. Legislation on this important question would seem to be an impossible approach in most cases. There would be many problems, including the possible deterioration in performance of the cabinet. Banks has suggested that consumer education will help. In the U.K., the British Standards Institution, with the collaboration of the manufacturers, has introduced a scheme which might help the consumer to exercise better judgment. Some types of cabinets are now given an identification mark according to the operating temperature. It will be interesting to see whether this approach leads to some progress.

Lorentzen (Norway): I would like to make two comments. First, regarding the open sales cabinets which are of impossible design from a technical viewpoint, but which we cannot get away from because the sales people want them. We have made some investigations of the heat transfer in sales cabinets. The trouble is, of course, that heat radiation enters the top layer of goods and this heat has to be removed somehow. If you study the heat transfer between the air circulating over the product, you will find that you need a temperature difference of 10 to 15 degC (18 to 27 degF) to remove this radiation heat, so you have two possible solutions to the problem. If you want an open box you must either see to it that the air circulating over the top of the product is 10 to 15 degC lower than the product temperature you would like to have, and this is very difficult to achieve, or another solution is to reduce the radiation coming into your product. There was a publication quite recently in Sweden concerning trials with foil-wrapping of the product. We have done the same thing with similar results. The radiation absorption by aluminium surface is just about 3 or 4 per cent of that for an ordinary package—a bit more if you print it. If you could get people to use aluminium wraps, like those for butter or margarine, you would lick this problem of high temperatures in the sales cabinets. It might be worthwhile to investigate this a bit further. We are just working on another possibility now —the experiments were started just as I left home—with some new forms of radiation shields which may help a bit. However, I think that the most practical solution would be to use some sort of laminated foil wrappings for frozen foods.

The other point concerns the very important question of the freezer chain and quality changes in the freezer chain. Some of you may know that we made quite an extensive investigation of this a few years ago, measuring thousands of temperatures in all the links of the chain, and also observing residence time of the products in each link of the chain. This gave us statistical material of sufficient size to make it possible, by using the methods indicated by Dr. Scott, to find out what the quality spectrum would be at each stage throughout the entire freezer chain if you suppose that the product is alright when it starts out from the freezing plant. With the temperature spectra and the spectra of residence times we had in the various stages, we estimated that the consumer product was one-third of very excellent quality, one-third of a fairly good quality and about 25 per cent or so of an acceptable but not very good quality, and then at the end some 8 per cent, as I recall it, of really poor quality, with 3 or 4 per cent being very poor. The analysis of this material showed a lot about the temperatures, which you can't do much about, but the main problem is to control residence time in the various cold stores and in the sales cabinets and to prevent products from being left over in odd corners and inaccessible places, only to come out eventually and create problems. I believe we should concentrate first and foremost on this problem of getting the circulation as uniform as possible. If anybody is interested in this material it is available in the *Proceedings of the British Institute of Refrigeration*, I think somewhere about '62 or '63.

Bramsnaes (Denmark): In summing up this question, I think it looks as if we may have to accept the fairly unhappy conditions for cabinet storage and for some years live with fairly warm temperatures in the cabinets and perhaps also the wholesale dealers. One of the means of improving this situation has been mentioned by Symons and also Lorentzen—that is to have as low temperature in the producers' cold stores as possible so that the product may have lost as little as possible of its storage life when it leaves the producer's cold storage. I also think that another means of improving conditions has been mentioned in a couple of the papers—namely the very great improvement you can get by using better packaging. There is a very obvious example in the way salmon and halibut steaks have been sold up to quite recent years in non-vacuum packs, pouches. I know of one survey which was done about five years ago, which showed that nearly all the samples purchased were, if not inedible, then marked pretty much down by the taste panel. Vacuum packing in pouches has started to appear on the retail market and I think that it has made a definite improvement on the quality of these products. The same is true if you look at some of the pre-cooked foods. I think our papers from Copenhagen show the need for vacuum packing some of these products in order to get a reasonable storage life under the conditions of distribution which I'm afraid we will have to live with for some time.

Harrison (FAO): I would just like to pose a question. I wonder if the trend in the industry towards vertical integration and also the trend to diversification of the handling of other products as well as fish, and the desire to maintain the prestige of a brand name, will have any impact on this problem of poor handling and poor conditions in the distribution chain? In posing this question, I am anticipating that with vertical integration and diversification in food items, the increased volume of business should make it economically feasible for the producer to supervise the handling and distribution of his products further into the distribution chain.

Slavin (U.S.A.): I think that this will help, particularly in the United States. However, I believe there are also quite a few vertically integrated companies in Europe. In a lot of cases, frozen fish is probably not as acceptable as it should be. However, it is difficult to vertically integrate the retailer. Perhaps we should do what O'Sullivan suggested and take a fresh look at whether we have a really acceptable product. I think that the comments tend to indicate that, at best, this product could be improved considerably. By improvement, I don't particularly mean quality, because that may not be the real problem. By improvement I mean improved in such a manner, whatever that may be, that you can sell more of it at a higher price. I submit that, at best, it is now sold at a fairly low price and doesn't have a great deal of acceptability. Lorentzen mentioned aluminium foil being used for margarine. In the United States margarine sells for around 39 cents or so a package while frozen fish sells for something like 65 cents a pound.

O'Sullivan (Ireland): I can see the problems associated with the introduction on consumer packages of frozen fish. In Ireland, when we were considering various approaches towards raising the standard of frozen fishery products right through to consumer level, we rejected the dating of packs

approach generally for the reasons mentioned by Little. We did, however, in association with the Irish Institute for Industrial Research and Standards (IIRS), embark during the past year, on a programme directed towards the raising of standards for processed seafood products—covering only a certain range of frozen seafood products so far, but being extended to eventually cover all processed seafood products. The Institute has developed standards for products and licenses processors to use their symbol on packs. The standards are strictly consumer standards and cover all factors relating to the product that would influence the consumer. The Institute sets very high standards in relation to the processors' premises, quality control arrangements, equipment and so forth, and guards the symbol jealously. Both the Institute and B.I.H. promote the symbol as having a real meaning at consumer, institutional and catering levels and although the programme is just some months underway, it is already having its effect.

I cannot agree that it is unfair to hold the producer responsible for what happens at retail level. We, as a Development Corporation, have a vested interest in high quality standards and the owners of brand labels should have an interest in ensuring that their brand image is not impaired by bad practice anywhere throughout the complete frozen chain. If we are to achieve our fisheries development objectives and they are to achieve their company's growth (or increase in value of shareholders' equity), the two sets of objectives must be compatible. The brand proprietor owns the brand and has a deep interest in consumers' attitudes towards it, not alone to retail level, but to the stage at which the consumer uses the product. Most responsible companies do not have to be reminded of their responsibilities in this respect.

The Institute inspectors, under their licence agreement with a processor, have the right to sample products at any stage—at the end of the production line, in cold storage (either on or off the processors' premises) or from a frozen food cabinet in a retail store and have the right to deprive the processor of the use of the IIRS symbol on their packs. It is premature to predict how effective the whole programme will be, since this depends very much on the marketing success of establishing a consumer demand for products bearing the symbol. We will know much more a year or two from now, but the whole programme looks promising at this stage.

PART VI

PRESERVATION OF FISHERY PRODUCTS BY IRRADIATION

THE QUALITY ASPECTS OF SEAFOOD IRRADIATION

Quality Indices that can be used to Assess Irradiated Seafoods . . *J. Spinelli, G. Pelroy and D. Miyauchi*

Quality Assessment and Consumer Acceptance of Irradiated Seafoods . . . . *J. M. Shewan and G. Hobbs*

Pruebas de Radurización de Filetes de Pescado Fresco y de Arenques Ahumados Conservados a Diferentes Temperaturas . . . . *D. de la Sierra Serrano*

Effect of Irradiation on the Keeping Quality of Packaged Cod Flesh *J. van Mameren, K. J. A. van Spreekens, H. Houwing and D. A. A. Mossel*

Preliminary Experiments on the Use of Irradiation to Destroy Enteropathogenic Bacteria on Freshwater Fish *D. A. A. Mossel and K. J. A. van Spreekens*

Effect of Irradiation on *Anisakis* Larvae in Salted Herring *J. van Mameren and H. Houwing*

Irradiation Inactivation of Food Infection Micro-organisms in Seafoods . . . . . *A. W. Anderson*

Effects of Multiple Dose Irradiation on the Bacterial Flora of Seafoods *J. Liston, A. M. Dollar and J. R. Matches*

Irradiation Cleavage of Trimethylamine Oxide in Fish Muscle . . . . *K. Amano and H. Tozawa*

Complementary Effect of Food Preservative and Gamma Radiation Treatment of Whale and Horse Mackerel Flesh *T. Tomiyama, S. S. Jeng, E. Shiraishi, M. Hamada and Y. Yamada*

Discussion

PRESENT STATUS AND CONSIDERATIONS REGARDING WHOLESOMENESS

Status of Legislation on Irradiated Food *H. E. Goresline*

Status of Research on Irradiated Fish and Shellfish in the United States . . . *L. J. Ronsivalli, J. D. Kaylor and J. W. Slavin*

Present Status of Radiation Preservation of Fish and Fishery Products in Europe *G. Hobbs and J. M. Shewan*

Irradiación de Productos de la Pesca—Posibilidades Españolas . . . *D. de la Sierra Serrano*

L'expérience italienne dans le secteur de la radiopasteurisation des produits de la pêche *D. Massa and A. Perna*

Discussion

ECONOMIC ASPECTS AND PRODUCTION TECHNOLOGY

Economic Feasibility of Radiopasteurization of Fish *L. W. van Meir*

Irradiation of Fish at Sea . *J. H. Carver, T. S. Connors and J. W. Slavin*

Meat Colour Regeneration in Frozen Tuna by Irradiation *K. Amano and H. Yamanaka*

Discussion

Quality Indices that can be used to Assess Irradiated Seafoods

by J. Spinelli, G. Pelroy and D. Miyauchi

Quality indices that can be used to assess irradiated seafoods

Tests for objectively assessing the quality of irradiated fish were divided into two classes: (1) those that correlated with sensory changes that occurred during storage and were therefore applicable in objectively testing irradiated fish and (2) those that showed poor correlation with sensory changes and were not particularly applicable in assessing the quality of irradiated fish.

Total bacterial counts, volatile acid numbers, nucleotides, hypoxanthine and extractable myofibrillar protein in fish showed the best correlation with sensory changes in irradiated fish stored at 33°F (0.5°C). Trimethylamine (TMA) did not correlate with sensory changes in fish irradiated at doses above 0.15 Mrad; at doses below 0.15 Mrad, TMA showed fairly good correlation with sensory changes.

Changes in histamine, low-molecular-weight carbonyls, thiobarbituric acid number, and free ribose in fish did not correlate with sensory changes in irradiated fish stored at 33°F (0.5°C).

Indices de qualité applicables aux produits marines irradiés

Des essais effectués en vue d'évaluer la qualité du poisson irradié ont été divisés en deux groupes: (1) les essais portant sur les changements sensoriels intervenant en cours d'entreposage, et par conséquent applicables à l'évaluation objective du poisson irradié et (2) les esais ne pouvant montrer qu'une faible corrélation avec les changements sensoriels et qui par conséquent ne sont pas spécifiquement applicables à l'évaluation de la qualité du poisson irradié.

La numération bactérienne totale, les indices d'acide volatil, les nucléotides, l'hypoxanthine et la protéine myofibrillaire extractible ont montré une corrélation maximale avec les changements sensoriels dans le poisson entreposé à 33°F (0,5°C). La triméthylamine (TMA) n'était pas associée aux changements sensoriels dans le poisson irradié à des doses supérieures à 0,15 Mrad; à des doses inférieures à 0,15 Mrad, la TMA révélait une assez bonne corrélation avec les changements sensoriels.

Les changements affectant l'histamine, les carbonyles de faible poids moléculaire, l'indice d'acide thiobarbiturique et le ribose libre n'étaient pas associés aux changements sensoriels dans le poisson irradié entreposé à 33°F (0,5°C).

Indices de calidad que se pueden utilizar para determinar la de los alimentos marinos irradiados

Las pruebas para determinar objetivamente la calidad del pescado irradiado se dividieron en dos clases: (1) las que están correlacionadas con cambios organolépticos que tienen lugar durante el almacenamiento y que, por lo tanto, se utilizaron para probar objetivamente el pescado irradiado; (2) las que tienen escasa relación con los cambios organolépticos y que no se aplicaron especialmente para determinar la calidad del pescado irradiado.

Los recuentos de bacterias totales, los índices de ácidos volátiles, los nucleótidos, la hipoxantina y las proteínas miofibrilares extraibles del pescado indicaron la mayor correlación con los cambios organolépticos en el pescado irradiado almacenado a 33°F (0,5°C). La trimetilamina (TMA) no mostró relación con los cambios organolépticos del pescado irradiado en dosis superiores a 0,15 Mrad; en dosis inferiores a 0,15 Mrad, la trimetilamina indicó bastante correlación con respecto a dichos cambios.

Los cambios registrados en la histamina, los carbonilos de poco peso molecular, el índice de ácido tiobarbitúrico y la ribosa libre en el pescado no estuvieron en relación con los cambios organolépticos en el pescado irradiado almacenado a 33°F (0,5°C).

FISH is an extremely perishable product, and the factors that contribute to its quality between catching and its preparation for retailing are numerous. The types of changes and the rates at which they occur are determined by the processes to which the fish may be subjected and the intrinsic properties of the fish itself. The irradiation process, by virtue of destroying and inactivating a large segment of the bacterial population, delays the development of "fishy" flavours and odours commonly associated with fish of poor quality. Irradiation does not, however, prevent autolytic reactions, which affect the ultimate quality of the fish and make it distinguishable from freshly-caught fish. Miyauchi and his associates (1964) pointed out that the changes that occur in irradiated fish may generally be divided into three classes:

(1) Those changes that are induced as a result of the fish substrate being exposed to ionizing radiation.

(2) Those changes that occur immediately after death and during the extended storage period.

(3) The chemical changes that are brought about by the slow regrowth of micro-organisms.

These investigators and others have also shown that existing values attached to some test methods currently used to assess the quality of fresh and frozen fish objectively are not always applicable with irradiated fish.

OBJECTIVES

The objectives of the work presented here are as follows:

(1) To determine the concentration of various chemical constituents that are formed, altered or utilized in stored irradiated fish.

(2) To correlate these findings with sensory changes for the purpose of objectively assessing and defining some of the quality alterations that occur in irradiated fish.

(3) To utilize these findings in formulating a basis for the intelligent production and control of irradiated fish.

RATE OF CHANGE OF SOME QUALITY ATTRIBUTES IN LOW-DOSE IRRADIATED FISH

Radiation-pasteurized fish degrade in quality in a stepwise fashion. The general pattern of sensory changes that occur in fish stored at 33°F (0.5°C) after irradiation at 0.2 Mrad and the objective tests that best reflect these changes are shown in fig 1. Sensory changes take place between three and 14 days of storage. Since these changes occur in the relative absence of microbiological growth, they can best be monitored and correlated with sensory changes by measuring certain autolytic changes that are known to occur in fish *post-mortem*. During the second and third weeks of storage, the rate of sensory change is

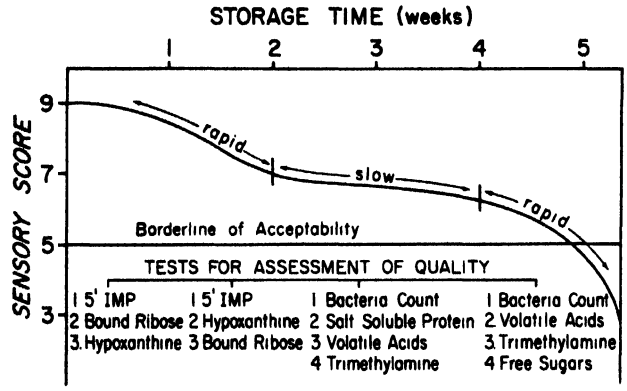


Fig 1. The rate of sensory change that generally occurs in fish irradiated at 0.2 Mrad and stored at 0.5°C (33°F). Indicated are the objective tests that best correlate with these changes

slow. Although micro-organisms are actively growing during this storage interval (fig 2), the metabolic end products produced by these organisms seem to have little influence on the sensory characteristics of the fish. Changes affecting texture are in evidence during this storage period and are reflected in a toughening or softening of the tissue. After four weeks of storage at 33°F (0.5°C), sensory changes are rapid and are microbiologically induced as evidenced by high bacterial numbers, production of various metabolic end products, and the disappearance of some tissue substrates.

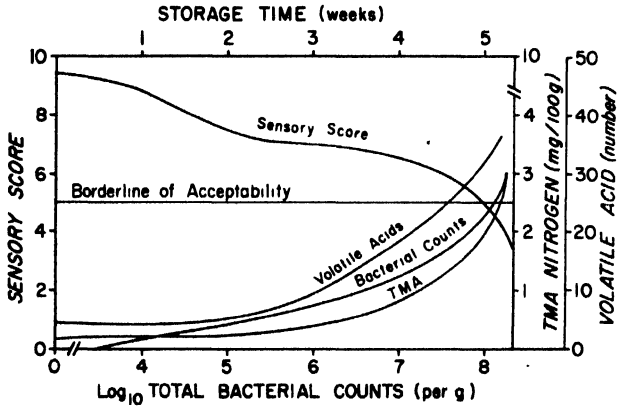


Fig 2. The relation between bacterial counts, TMA, VAN and sensory scores in fish irradiated at 0.2 Mrad and stored at 0.5°C (33°F)

The changes that occur in irradiated fish are numerous, spanning the gamut of changes that can occur in both fresh and processed fish. Several tests have been screened by determining the relation between test values and the sensory changes that take place in stored irradiated fish. Tests have been separated into two categories as follows:

(1) Those that show some correlation with sensory changes during storage and are therefore applicable in objectively assessing the quality of irradiated fish.

(2) Those that show little or no correlation with sensory testing and that therefore have limited applicability in the assessment of the quality of irradiated fish.

APPLICABLE TESTS

Materials and methods

Fish. All the fish used in these studies, unless otherwise specified, were obtained from commercial vessels and, depending upon the species, were from one to seven days old when landed. Filleting of the fish was done at commercial filleting plants in the presence of Bureau personnel.

IMP and hypoxanthine. Perchloric extracts were made of 40 g of fish tissue (Spinelli *et al.*, 1964). IMP was measured on the neutralized extracts by the method of Spinelli and Kemp (1966); hypoxanthine, by the method of Kalckar (1947).

Bound ribose. Neutralized perchloric extracts were made alkaline to pH 10.5 with 10 per cent NH_4OH. An aliquot usually representing about 2.5 g of fish was passed over a 1×2 cm column containing Dowex 1-X8(Cl^-) resin (200 to 400 mesh). Under these conditions the nucleosides will be retained by the column (Jones and Burt, 1960). IMP and ribose phosphate are also retained by the column. Elution is carried out with three 5-ml portions of 4NHCl followed by 10 ml of water. Total ribose was determined in the effluent by the method of Mejbaum (1957).

Trimethylamine (TMA). Method of Dyer (1945).

Volatile acid number (VAN). Official Methods of Analysis, Association of Official Agricultural Chemists (1955).

Salt soluble and myofibrillar protein. As described by Dyer *et al.* (1950). Protein fractions were determined by the method of Lowery *et al.* (1951).

Glucose. An aliquot of neutralized perchloric acid extract representing about 2.5 g of fish was passed over a 1×2 cm column containing Dowex 1-X8(Cl^-) resin. Free glucose was determined in the effluent with anthrone by the method of Morris (1948).

Total bacterial counts. Fifty grams of tissue was removed from several fillets and determination was made as described by Pelroy and Eklund (1966).

RESULTS AND DISCUSSION

Inosine monophosphate

5' inosine monophosphate (IMP) occurs in fish tissue as the de-amination product of adenosine monophosphate. The flavour-enhancing properties of IMP have been established by several investigators (Kuninaka *et al.*, 1964; Titus, 1964); its relation to the flavour of irradiated fish is the subject of a separate communication (Spinelli and Miyauchi, 1967). Figure 3 shows the relation between the degradation of IMP, the accumulation of hypoxanthine and the sensory changes that occurred in Pacific ocean perch (*Sebastodes alutus*) that had been irradiated at 0.2 Mrad and stored at 33°F (0.5°C). The value of IMP determinations lies in the fact that its rate of degradation is not particularly influenced by microbiological growth. Hence, it is useful in determining the pre-irradiated

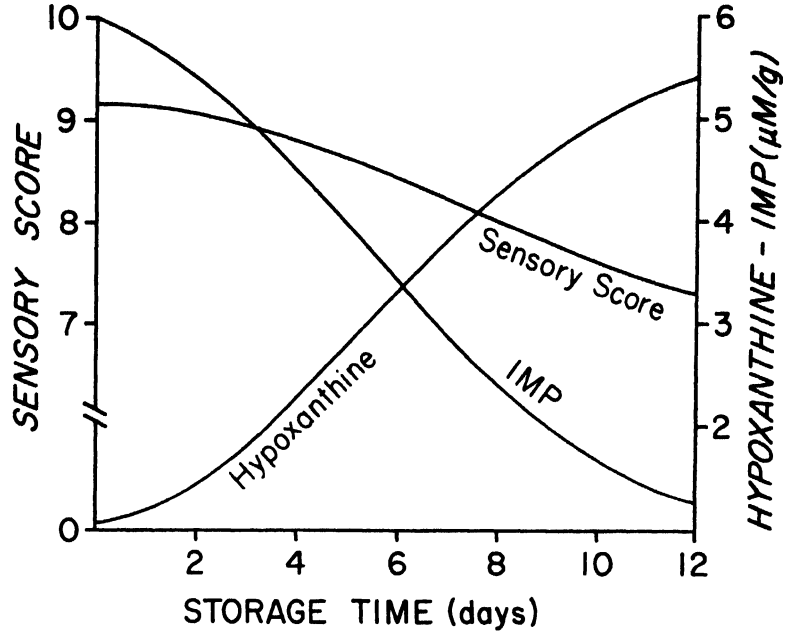


Fig 3. Relation between IMP, hypoxanthine and sensory score in Pacific ocean perch fillets irradiated at 0.2 Mrad and stored at 0.5°C (33°F)

condition of the fish and in assessing to some degree the length of time the fish has been stored in ice. The rate of IMP degradation is a function of the species, and these specific rates must be established if useful information is to be derived from this test.

Hypoxanthine and bound ribose

Hypoxanthine accumulates in fish tissue as the hydrolytic end product of IMP via inosine. As is the case with IMP, (its rate of accumulation also varies with the species Kassemsarn *et al.*, 1963; Spinelli, Eklund and Mujauchi, 1964). Since the rate-limiting step in the production of hypoxanthine is dependent on the nucleosidase activity of the fish tissue, hypoxanthine in most species of fish continues to accumulate after the degradation of IMP. With several species of fish suitable for irradiation, hypoxanthine will reach maximum concentration after 10 to 18 days of storage. Its measurement therefore offers a useful index regarding the length of time fish has been ice-stored.

The measurement of bound ribose yields essentially the same information as does the measurement of hypoxanthine. Bound ribose determinations may be preferred in some quality control laboratories, since neither an ultraviolet spectrophotometer nor an active enzyme is necessary. The relation between hypoxanthine and bound ribose is shown in fig 4.

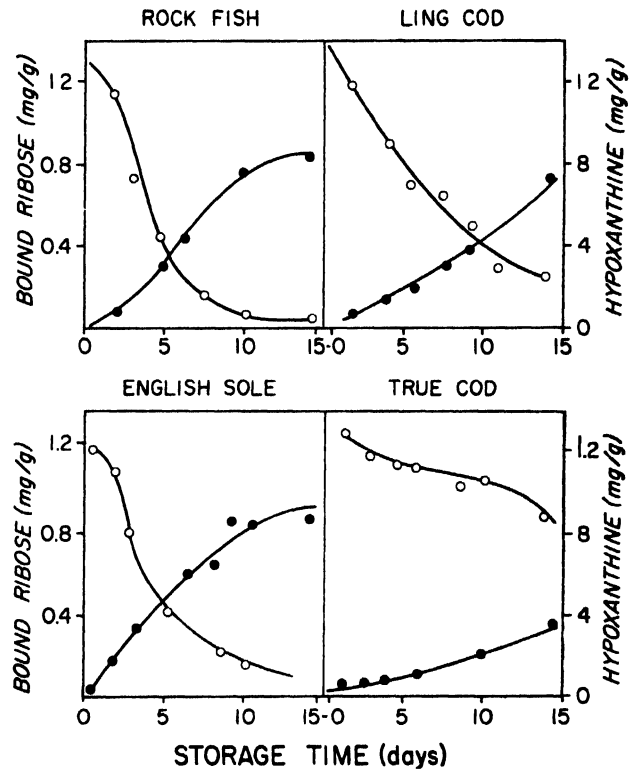


Fig 4. Relation between hypoxanthine and bound ribose values in four species of fish stored at 0.5°C (33°F)

Bacterial counts, trimethylamine and volatile acids

The determination of total bacterial numbers and some of their metabolic end products such as trimethylamine (TMA) and volatile acids have proved to be useful quality indicators of fresh and processed fish. Some investigators (Hillig *et al.*, 1958) have placed fish in five organoleptic classes depending on the amounts of TMA, volatile acids and volatile bases that are found in the fish. This system works quite well with non-irradiated fish because the mixed bacterial flora that contaminates iced fish yields typical and recognizable spoilage patterns. Irradiated fish, however, has been shown to have a fairly select bacterial population, and the number of bacteria required to induce sensory changes in irradiated fish is considerably higher than in non-irradiated fish (Spinelli *et al.*, 1965). These investigators showed that the surviving bacteria that grow on irradiated fish are generally non-

proteolytic and that the amount of free bases that are produced during storage is much less than the amount produced in non-irradiated fish.

The determination of total bacterial numbers, TMA and volatile acids does, however, provide useful information regarding quality and potential storage life of irradiated fish. The general relation between bacterial count, TMA, volatile acids and sensory scores in petrale sole (*Eopsetta jordani*) fillets irradiated at 0.2 Mrad is shown in fig 2. This relation has been shown to be quite consistent with all species of fish that we have studied. The effect of a select bacterial population on the production of TMA becomes readily apparent when the amount of TMA in spoiling irradiated fish is related to dose (fig 5). It can be seen that the utility of TMA as a quality index is applicable only to fish irradiated below 0.2 Mrad. The production of volatile acids, on the other hand, are not particularly influenced by irradiation dose (fig 6), and the amount of volatile acids found is closely related to sensory changes.

Although total bacterial counts provide useful information regarding the potential storage life of irradiated fish, they are time-consuming to perform. Some work has been done in measuring the rate of reduction of resazurin dye in estimating bacterial counts in fillets. The relation between bacterial counts and the number of hours required for dye reduction in fish irradiated at 0.2 Mrad

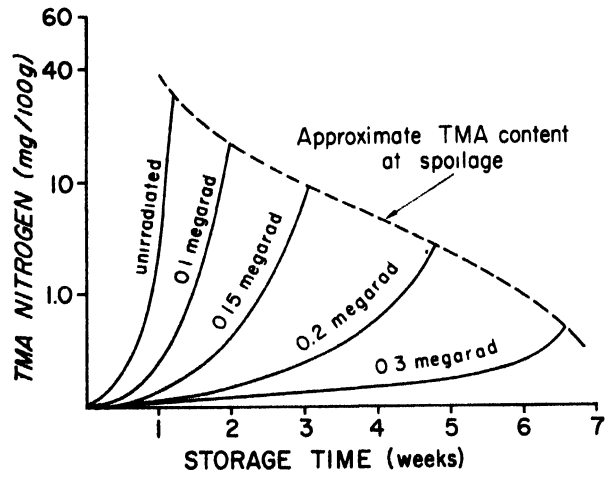


Fig 5. The relation between irradiation dose and the amount of TMA found in fish at the time of spoilage

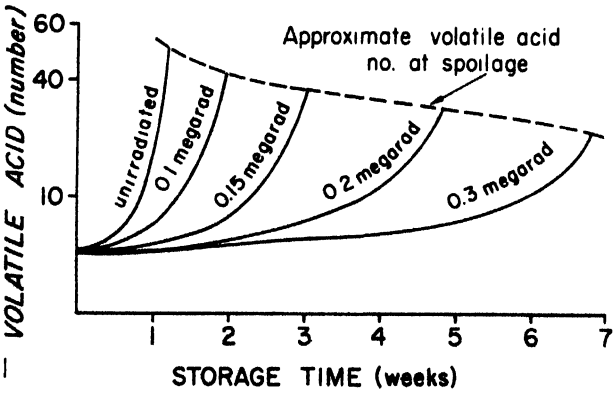


Fig 6. The relation between irradiation dose and VAN in fish at the time of spoilage

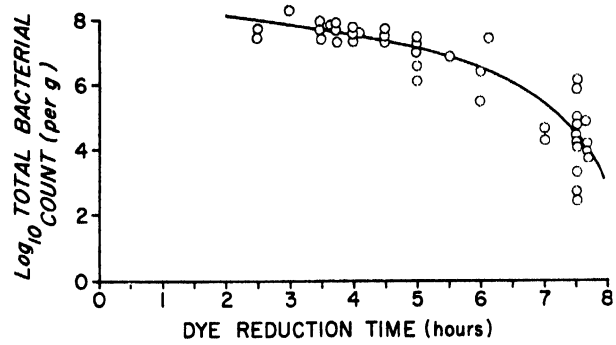


Fig 7. Estimation of bacterial counts using resazurin dye reduction

is shown in fig 7. Although the relation between the dye-reduction time and bacterial counts is not ideal, with adequate sampling, mean dye-reduction times of less than 5 h would probably be indicative of borderline fish.

Salt-extractable proteins

Textural alterations in fish are complex, and factors relating to those alterations are not completely understood. It is agreed, however, that denaturation of the myofibrillar fraction of the tissue proteins is implicated in these changes. Generally speaking, texture is not considered to be a problem with fresh fish, and there is little information in this area that relates protein alteration with texture.

In some of our experiments, salt-soluble and myofibrillar proteins were measured periodically in Pacific ocean perch and English sole (*Parophrys vetulus*) that were irradiated at 0.2 Mrad and stored at 33°F (0.5°C). The fish used in these experiments were three days old when landed. At each sampling interval, three fillets were sampled; the samples for analysis were taken from the centre cross section of the fillets.

The mean value of these analyses are shown in fig 8. Significant changes in salt-soluble protein occurred after about three weeks of storage. Extractable myofibrillar protein decreased progressively during storage of the perch but did not begin to decrease significantly in the sole until after two weeks of storage. The texture scores shown in fig 8 do not represent the same fillets on which the protein determinations were made but are mean values taken from other experiments that were made to determine the texture characteristics of stored irradiated fillets. Interestingly enough, the reaction of the taste panel was that texture changes in the perch were due to a toughening effect, whereas in the sole softening of the tissue was the cause of poor texture. Softening in the sole was not the result of protein degradation, since non-protein nitrogen and tyrosine values were essentially constant throughout the storage period.

From the data, it would appear that the amount of myofibrillar protein that is extracted with buffered 5 per cent salt reflects texture alterations in the stored irradiated fish that were used in this study. The method has drawbacks in that it is time-consuming to perform and particular care must be exercised in sampling and in performing the test (Jebsen, 1965).

Physical measurements to assess textural changes objectively in raw fillets were made using a shear press

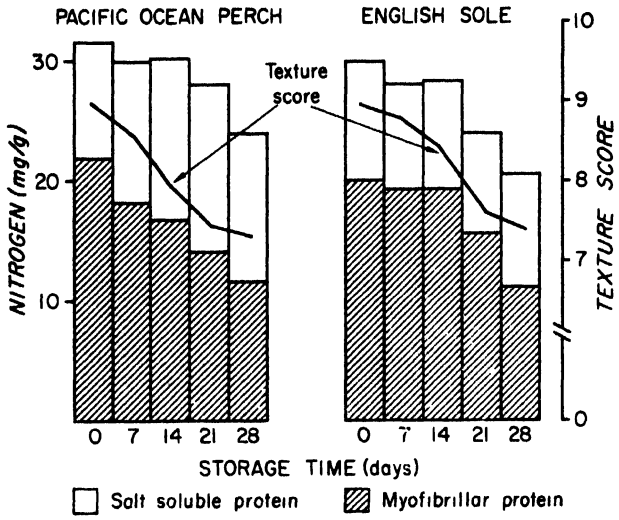


Fig 8. The relation between salt-soluble nitrogen, myofibrillar nitrogen, and texture scores in Pacific ocean perch and English sole fillets irradiated at 0.2 Mrad and stored at 0.5°C (33°F)

(Dassow, McKee and Nelson, 1962); the results were inconclusive. The cell fragility method described by Love and MacKay (1962) was not evaluated.

Free glucose

The measurement of free glucose in irradiated Pacific ocean perch fillets shows that the glucose is gradually consumed during storage. Several experiments with Pacific ocean perch show that mean initial glucose value of 20 mg/100 g gradually declines to 1.4 mg/100 g as the product enters the spoilage phase. Glucose, like other constituents of the tissue, is found in varying amounts so its utility as a quality index would depend on sound statistical sampling coupled with its relation to other indices.

TESTS OF LIMITED APPLICABILITY

Methods

Histamine determination. Kawabata (1960).

Thiobarbituric acid number (TBA No.). Determined on whole fish by the method of Yu and Sinnhuber (1957).

Low molecular weight carbonyls. Determined by the method described by Ota (1958).

Free ribose. Phosphorylated compounds and nucleosides were removed from perchloric acid extracts as previously described, and ribose was determined by the method of Mejbaum (1957).

RESULTS AND DISCUSSION

Histamine

Histamine, a physiologically active compound, is produced by the enzyme l-histidine decarboxylase. The enzyme is elaborated by several micro-organisms and has also been reported to be a normally occurring enzyme in fish tissue (Kimata, 1961). Histamine was monitored in two species of fish [halibut (*Hippoglossus stenolepsis*) and petrale sole]. The results of one set of experiments in which petrale sole fillets were irradiated at 0, 0.1, 0.2, 0.3 and 0.4 Mrad is shown in table 1. Similar values were obtained with halibut. Since histamine shows no appreciable increase in irradiated fish until obvious spoilage occurs, this compound does not appear to be a useful indicator of product quality. Also, it does not increase in sufficient quantity (even in spoiled fish) to make it physiologically important.

TABLE 1. FORMATION OF HISTAMINE IN VACUUM-PACKED PETRALE SOLE FILLETS IRRADIATED AT 0, 0.1, 0.2, 0.3 and 0.4 MRAD AND STORED AT 33°F (0.5°C)

Storage time	*Concentration of histamine in fillets irradiated at (Mrad)*				
	0	0.1	0.2	0.3	0.4
Days	mg/100 g	mg/100 g	mg/100 g	mg/100 g	mg/100 g
0	0.8	0.50	0.50	0.72	0.72
5	0.0	—	—	—	—
7	3.0*	0.60	0.60	—	—
8	4.5	—	—	—	—
14	—	0.42	0.50	0.40	0.40
21	—	2.4*	0.70	0.40	0.55
28	—	—	0.70	0.80	0.80
35	—	—	0.85*	0.65	0.85
42	—	—	1.7*	0.70	0.70
49	—	—	—	1.2*	0.85

* Samples spoiled.

Thiobarbituric acid number

When some species of fish are irradiated in an atmosphere of air, rancidity will develop in portions of the fish that are exposed to the air in the package. Vacuum packing or packing of the fish so that air is essentially eliminated from the container can eliminate this problem (Miyauchi *et al.*, 1964).

The objective assessment of rancidity in irradiated fish was measured by determining the TBA number of the fish. We found that the relation between TBA number and detectable rancidity was poor. The problem with the poor correlation probably lies in the way rancidity develops in the fish. Rancidity is almost always localized; often only one or two fillets from a package become rancid. In other cases, only a small spot on the fillet will be rancid. This type of variation is undoubtedly reflected in the relation between TBA number and detectable rancidity, making it difficult to interpret the data. We have not investigated the determination of TBA numbers on oil extracted from irradiated fish, which conceivably could yield more useful information than when the determination is made on the whole fish.

Low molecular weight carbonyls

The amount of low-molecular-weight carbonyls was determined in air- and vacuum-packed king crab. With vacuum-packed crab, initial carbonyl values of 0.5 mg/100g (calculated as acetaldehyde) increased to approximately 1.0 mg/100g only when the product reached the spoilage phase. With the air-packed product, carbonyl values generally decreased during storage and only showed significant increases when the crab was definitely spoiled.

Free ribose

Several investigators have suggested that free and phosphorylated sugar not only contributes to the flavour of fish but also might be useful as quality indicators (Shewan and Jones, 1957; Burt, 1965). Our work in the latter area shows that ribose, as suggested, increases during early storage and with non-irradiated fish progressively decreases; the decrease is closely related to microbiological activity. With irradiated fish, however, only slight decreases were found in the free ribose content until spoilage was definitely in evidence. It was interesting to find that even in advanced spoilage, only about one third of the original ribose content of the tissue has been consumed. The utility of free ribose as a quality index in irradiated fish therefore remains doubtful.

CONCLUSIONS

Quality changes in low-dose irradiated fish are rapid in the early and terminal phases of storage. Early quality changes, which are reflected primarily by loss of flavour, are caused by autolytic processes and can be correlated with the degradation of IMP and the accumulation of hypoxanthine.

Except for textural alteration that appears to correlate with alteration of the myofibrillar protein, flavour and odour are rather stable until bacterial counts approach 10^7/g. The amount of volatile acids that accumulate in the tissue shows good correlation with these latter sensory changes. TMA, depending on the dose, can also be related to sensory change. In the terminal phase of storage, bacterial counts approach 10^8/g; VAN exceed 20, and about 75 per cent of the free glucose originally present in the tissue has been consumed. Histamine, low-molecular-weight carbonyls, and free ribose showed only slight changes during normal storage and bore little if any relation to the quality of the irradiated fish. TBA numbers determined on whole fish did not accurately reflect the development of rancidity in irradiated fish.

References

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS *J. Ass. off. agric. Chem.*, 8th ed., p. 312. (Methods of Analysis.) 1955

BURT, J R In *The Technology of Fish Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 176. 1965

DASSOW, J A, MCKEE, L G and NELSON, R W *Fd Technol., Champaign*, **16**(3), 108. 1962

DYER, W J *J. Fish. Res. Bd Can.*, **6**, 351. 1945

DYER, W J, FRENCH, H V and SNOW, J H *Ibid.*, **7**, 585. 1950

HILLIG, F, SHELTON, L R J, LOUGHERY, H and EISNER, J *J. Ass. off. agric. Chem.*, **41**, 763. 1958

JEBSEN, J W In *The Technology of Fish Utilization*, ed. R. Kreuzer, Fishing News (Books) Ltd., London, p. 61. 1965

JONES, N R and BURT, J R *Analyst, Lond.*, **85**, 810. 1960

KALCKAR, H M *J. biol. Chem.*, **167**, 429. 1947

KASSEMSARN, B O, SANZ-PEREZ, B, MURRAY, J and JONES, N R *J. Fd Sci.*, **28**, 28. 1963

KAWABATA, T *Bull. Jap. Soc. scient. Fish.*, **26**, 1183. 1960

KIMATA, M In *Fish as Food*, ed. G. Borgstrøm, Academic Press, New York, **1**, 329. 1961

KUNINAKA, A, KIBI, M and SAKAGUCHI, K *Fd Technol., Champaign*, **18**(3), 29. 1964

LOVE, R M and MACKAY, E M *J. Sci. Fd Agric.*, **13**, 200. 1962

LOWERY, H O, ROSEBROUGH, N J, FARR, L A and RANDALL, R J *J. biol. Chem.*, **193**, 265. 1951

MEJBAUM, W *Manometric Techniques*, Burgess Publishing Co., p. 274. 1957

MIYAUCHI, D, SPINELLI, J, PELROY, G and STOLL, N Application of radiation-pasteurization process to Pacific crab and flounder. *Report TID* 22515, Division of Technological Information, U.S. Atomic Energy Commission, p. 35. 1965

MORRIS, D L *Science, N.Y.*, **107**, 254. 1948

OTA, F *Bull. Jap. Soc. scient. Fish.*, **24**, 334. 1958

PELROY, G A and EKLUND, M W *Appl. Microbiol.*, **14**, 921. 1966

SHEWAN, J M and JONES, N R *J. Sci. Fd Agric.*, **8**, 491. 1957

SPINELLI, J and KEMP, B *J. agric. Fd Chem.*, **14**, 176. 1966

SPINELLI, J and MIYAUCHI, D *J. Fd Sci.* (MS.) 1967

SPINELLI, J, EKLUND, M and MIYAUCHI, D *Ibid.*, **29**, 710. 1964

SPINELLI, J, EKLUND, M, STOLL, N and MIYAUCHI, D *Fd Technol., Champaign*, **19**(6), 126. 1965

TITUS, D S *Symposium on Flavor Potentiation*, Arthur D. Little Inc., p. 10. 1964

YU, T C and SINNHUBER, R *Fd Technol., Champaign*, **11**(2), 104. 1957

Quality Assessment and Consumer Acceptance of Irradiated Seafoods

by J. M. Shewan and G. Hobbs

Quality assessment and consumer acceptance of irradiated seafoods

The quality assessment of irradiated sea foods by analytical taste panel techniques shows that the outstanding sensory feature of such products is the presence of burnt or singed odours and flavours associated probably with the production of organic sulphides.

Few large-scale consumer tests of irradiated sea foods appear to have been carried out, apart from the use of products such as haddock and cod fillets in meals at United States Army Camps.

Evaluation de la qualité et acceptabilité par les consommateurs des produits marins irradiés

L'évaluation, par les techniques du jury de dégustation, de la qualité des produits marins irradiés, montre que la principale caractéristique organoleptique de ces produits est la présence d'odeur et de saveur de brûlé, probablement liées à la production de sulfures organiques.

En dehors de l'emploi de produits tels que les filets d'églefin et de morue servis dans les cantines des camps de l'Armée étatsunienne, il semble que l'on ait effectué peu d'essais à grande échelle sur l'acceptabilité de produits marins irradiés.

Determinación de la calidad y aceptación por los consumidores de alimentos marinos irradiados

La determinación de la calidad de alimentos marinos irradiados mediante las técnicas de análisis por grupo de catadores, demuestra que la característica sensorial más destacada de tales productos es la presencia de olores y sabores a quemado o chamuscado, probablemente relacionados con la producción de sulfuros orgánicos.

Al parecer, se han realizado pocos ensayos en gran escala entre los consumidores de alimentos marinos irradiados, exceptuado el uso de algunos productos como filetes de eglefino y bacalao en las comidas que se sirven en los campamentos del ejército de los E.U.A.

THE sensory assessment of the quality of a food product and in particular of new products such as irradiated sea foods is of fundamental importance to the development of irradiation as an alternative method of food preservation. The overall "eating quality" is best judged by an evaluation of the various sensory features or quality factors of the product, the most important of which are the appearance, odour and texture of the raw product, and the appearance, odour and flavour of the cooked one.

The difficulty arises as to the precise methods to be used for the evaluation of these various quality factors. Many believe that this can only be done satisfactorily by the use of the so-called analytical taste panel. Such a panel usually consists of from four to six members and for new products such as irradiated fish, should have had some experience in taste panel assessment, preferably of sea foods. Their main task is to identify and describe, in agreed, meaningful terms the sensory properties (appearance, odour, etc.) of the food stuff in both the raw and cooked states. Experience has shown that the attainment of agreed descriptive terms, e.g. of odours, is a most difficult one, although the use of a catalogue of description as given by Wagner (1950) and Harper (1966) can be of great assistance. If some of the odour descriptions can be aligned with pure chemical compounds, e.g. ammoniacal odours with ammonia—so much the better. Moreover, a panel, experienced in the quality assessment of almost any foodstuff, is more articulate in its approach to a new product than an untrained one. The build up of the descriptive terms may take some time, more particularly where the product, such as most sea foods, are subject to biological variations of all kinds due to season, sexual cycle, fishing area, method of capture, time and temperature of storage since capture and so on. However, it has been our experience with a variety of sea foods, as those of others, that an agreed set of descriptive terms for each quality factor, can be readily built up and by which the "eating quality" of the product can be defined at any point in its passage from absolute freshness to putridity (Dyer and Dyer, 1949; Shewan, MacIntosh and Tucker, 1953; Ehrenberg and Shewan, 1960). To expedite the use of such descriptive terms a score sheet can be devised, giving in shorthand as it were, the discernible points in the chain of events from freshness to putridity and this has now been accomplished for a variety of sea foods at Torry Research Station.

Having once set up a score sheet it can then be used for a variety of purposes such as assessing the effect on eating quality of any particular treatment, e.g. the use of antibiotic ice as against ordinary ice (Shewan, 1962).

In order that the results from the use of such a score sheet be valid, the number and choice of panel members, the number and selection of samples, the conditions, including consideration of certain psychological factors, under which the samples are examined and presented to the panel in both the raw and cooked states, all must be subject to rigorous statistical control. A consideration of all these factors in relation to taste panel assessment of fish such as cod (*Gadus morhua*) have been the subject of

a series of papers from Torry Research Station (Ehrenberg and Shewan, 1960) and need not be reiterated here. Suffice it to say that significant differences between two treatments can readily be arrived at by a panel of from four to six people, examining six random samples from each treatment.

TASTE PANELS AND IRRADIATED SEA FOODS

There seems to be little doubt that as a laboratory tool the analytical panel can be of great assistance in identifying the areas and of uncovering the sensory properties where two treatments differ most. Thus, with regard to irradiated fish, analytical taste panels have been used extensively to describe the effect of irradiation on the sensory quality factors of a wide range of sea foods, before, immediately after irradiation and during storage at various temperatures. An analysis of the results of several such panels indicates that probably the most significant sensory changes due to irradiation are the production of burnt, scorched or burnt-feather-like odours and flavours (Slavin, Ronsivalli and Connors, 1966; Power *et al.*, 1964), and a major part of the research now going on in the irradiation field is the identification of these odours and flavours (said to be linked with organic sulphides) and the suppression, masking or prevention of their occurrence during the irradiation process. There seems little doubt that if these undesirable odours and flavours could be eliminated, particularly with sterilizing doses, the value of irradiation as an alternative method of food preservation would increase enormously.

The data produced by an analytical panel has some limitations in its use. At best it can show whether there are any differences or not between two treatments and can help to identify any such differences in terms of individual quality factors. The main drawback is that it can give no indication of the acceptability of the products, either to the panel itself or to the general consumer. For consumer acceptability testing a variety of techniques has been devised (Amerine, Pangborn and Roessler, 1965). The simplest is to use the analytical panel, and ask its individual members to express an opinion as to whether the product is acceptable or not as an article of food, using a hedonic scale—usually over a nine-point range of "like extremely well" to "dislike intensely". It is hereby assumed that the panel can act in this way as normal consumers. It is more usual, however, to enlarge the analytical panel by incorporating volunteers from the laboratory, institute or university in which the work is being carried out. The numbers of such tasters ranges from 20 to 100 or more, but these are usually limited by the facilities available in the kitchen. It is generally assumed that the data obtained from such a panel is in some general way relevant to what would be obtained from the general consumer. In other words if the laboratory consumer likes a product then the general public would also like it. Many workers in this very difficult field of consumer testing would reject the general validity of such a claim, since a variety of factors such as age and social groups, food habits, methods of sales presentation (e.g. type of package), method of cooking and table presentation would all have to be statistically controlled and assessed. It is generally agreed that proper consumer testing of a food product such as irradiated sea foods where the above factors and several others are properly controlled, is an extremely costly business. Accordingly, it usually is only the large firms which are capable of undertaking such tests and are normally unwilling to disclose precise details.

AVAILABLE DATA

So far as irradiated sea foods are concerned the most extensive consumer testing yet undertaken has been with large-scale experimental lots served up to units of the American Army at Fort Lee, Virginia, as part of standard meals. Here a nine-point hedonic scale has been used in addition to an assessment of "plate residue" and the results analysed statistically (Slavin, Ronsivalli and Connors, 1966; Ketchum, Osburn and Deitch, 1965).

The products used have included haddock (*Melanogrammus aeglefinus*) and cod (*Gadus* spp.) fillets and shrimps, often of varying initial qualities before being submitted to varying irradiation pasteurizing doses and stored for varying periods in ice or at 0.6°C (33°F), before being served to the troops. The results appear to show that all the irradiated products were highly successful as standard troop meals. The relevance of such tests to general consumer reaction is unknown. One of the few attempts known to the authors to assess general consumer reaction to irradiated sea foods, is that of Novak and his colleagues at Louisiana State University with pasteurized Gulf oysters (*Crassostrea virginica*) (Novak *et al.*, 1966). The tests were carried out in five cities: Memphis, Louisville, Indianapolis, Chicago and Lafayette (Ind.), using oysters irradiated (0.2 Mrad) and unirradiated, stored in ice for periods up to 21 days and submitted in the raw and cooked state (fried in batter) to a panel of 25 individual consumers, using a hedonic scale. It is clear, however, from the data available that this is a rather limited consumer test. It must be concluded, therefore, as some authors have already done (Schultz and Lee, 1965), that while radiation pasteurization continues to look promising, the one thing lacking (irrespective of the wholesomeness aspects) is consumer opinion obtained in the market place.

This paper was prepared as part of the programme of the Torry Research Station.

References

AMERINE, M A, PANGBORN, R M and ROESSLER, E B 1965 *Principles and Sensory Evaluation of Food*, Academic Press, London.

DYER, F E and DYER, W J 1949 Changes in the palatability of cod fillets. *J. Fish. Res. Bd Can.*, **7**, 449–460.

EHRENBERG, A S C and SHEWAN, J M 1960 The development of use of a taste panel technique—a review. *Occup. Psychol.*, **34**(4), 241–248.

HARPER, R 1966 On odour classification. *J. Fd Technol.*, **1**, 167.

KETCHUM, H W, OSBURN, J W and DEITCH, J Current status
1965 and commercial prospects for radiation preservation of food. U.S. Dept. Commerce, Business and Defense Services Administration T.I.D.–21431.

NOVAK, A F, LIUZZO, J A, GRODNER, R M and LOVELL, R T
1966 Radiation pasteurization of Gulf Coast Oysters. *Fd Technol., Champaign*, **20**(2), 103–104.

POWER, H E, FRASER, D I, NEAL, W, DYER, W J, CASTELL, C H,
1964 FREEMAN, H C and IDLER, D R The use of gamma radiation for the preservation of scallop meat. Symposium on Chemical Engineering in the Fishing Industry, Part II. Boston, Mass., December.

SCHULTZ, H W and LEE, J S Food preservation by irradiation
1965 —present status in Radiation Preservation of Foods. Symposium 19th May 1965 in conjunction with 25th Annual Meeting of the Institute of Food Technology, Kansas City, Missouri, p. 48.

SHEWAN, J M The use of antibiotics in the preservation of fish.
1962 In *Antibiotics in Agriculture*, ed. M. Woodbine, Butterworth, London.

SHEWAN, J M, MACINTOSH, R G, TUCKER, G C and EHREN-
1953 BERG, A S C The development of a numerical scoring system for the sensory assessment of the spoilage of wet white fish stored in ice. *J. Sci. Fd Agric.*, **4**, 283–298.

SLAVIN, J W, RONSIVALLI, I J and CONNORS, T J Status of
1966 research and development studies on radiation pasteurization of fish and shellfish in the United States. In *Food Irradiation*, IAEA, Vienna.

WAGNER, K G Sprachliche Grundlagen der Sinnenprüfung
1950 von Lebensmitteln. *Z. Lebensmittelunters. u. -Forsch.*, **90**, 36.

Pruebas de Radurización de Filetes de Pescado Fresco y de Arenques Ahumados Conservados a Diferentes Temperaturas

por D. de la Sierra Serrano

Pruebas de radurización de filetes de pescado fresco y de arenques ahumados conservados a diferentes temperaturas

Los ensayos de control microbiológicos y físico-químicos efectuados en doscientas muestras de filetes de pescado fresco y arenques ahumados, confirman que la irradiación a las dosis de 0,2 a 0,35 Mrad, mejora la calidad higiénica y multiplica por 3 ó 4 veces la vida comercial del pescado, si es mantenido a la temperatura de 0° a 1°C (32° a 34°F). Las muestras irradiadas a las mismas dosis, pero conservadas a una temperatura de 6° a 8°C (43° a 46°F) sólo aumentan la vida comercial de 2 a 3 veces. El Irradiador Móvil Industrial (I.R.M.A.) con fuente de ^{137}Cs (175.000 ci) fue utilizado en la irradiación de productos.

Los análisis microbiológicos, antes y después de la irradiación de las muestras, ponen de manifiesto la utilidad de la irradiación como método de pasterización de los filetes de pescado. Estos se encuentran frecuentemente contaminados por gérmenes saprofitos-banales, fecales y algunas veces patógenos, que provienen de las manos y utensilios de trabajo. La microflora total inicial de 10^5 a 10^6 gérmenes/g, queda reducida en un factor de 10^3 a 10^5, según dosis.

La puesta a punto de medios de cultivo selectivos o no, ha permitido aislar y después identificar numerosos grupos de micro-organismos y revelar que la microflora dominante en el pescado, constituida por *Achromobacter*, *Pseudomonas*, es prácticamente eliminada la las dosis de radurización. Sólo queda una flora residual, formada por especies más resistentes a la irradiación tales como: levaduras, *Micrococcus*, *Sarcina* y *Bacillus*, la mayor parte saprofitos, que posteriormente se desarrolla y sustituye a la flora inicial.

Según la procedencia del pescado, se han encontrado distintos equilibrios cuantitativos de la flora bacteriana, mientras que el equilibrio cualitativo ha permanecido constante.

Los resultados obtenidos confirman, en general, los de otros autores que han estudiado la radurización del pescado. Los análisis detallados de la microflora nos dan una idea de las fuentes de contaminación que nos permitirá limitarlas antes de la aplicación del nuevo método.

Gamma irradiation trials on fresh fish and smoked herring fillets stored at different temperatures

Biological and physico-chemical assays on 200 samples of fresh fish fillets and salted and non-salted smoked herring show that irradiation at 0.2 to 0.35 Mrad doses improves and prolongs three or four times the shelf life of the product, provided that temperatures of 0° to 1°C (32° to 34°F) are maintained. Samples subjected to identical doses but stored at 6° to 8°C (43° to 46°F) have a shelf life of no more than two or three times that of products not so irradiated.

A 175,000 ci mobile industrial irradiation unit manufactured by I.R.M.A., having a ^{137}Cs source, was used.

Microbiological analysis before and after irradiation demonstrated the advantages of irradiation as a pasteurization technique for fish fillets. These are frequently found to be contaminated with saprophytes, some of no serious hazard, others of a faecal origin, and some that are pathogenic, from the hands of workers or the utensils employed. Initial microfloral counts of 10^5 to 10^6 pathogens/cm^2 are reduced to the 10^3 to 10^5 range, depending on the dose. Culture media, selective or otherwise, on which many groups of micro-organisms were first isolated and subsequently identified, were developed revealing that the predominant microflora in the fish, *Achromobacter* and *Pseudomona* can be virtually destroyed at the irradiation doses mentioned. A residual microflora, consisting of species more resistant to radiation such as the yeasts, *Micrococci*, *Sarcina* and *Bacilli*, are mostly saprophytic, developing after irradiation and replacing the initial microflora.

Depending on the provenance of the fish, different quantitative equilibria in the bacterial flora were encountered, whilst the equilibrium of the various types remained constant.

The findings confirm, for the most part, those of other authors that have worked on fish irradiation. Detailed analysis of micro-organisms may give an idea as to the sources of contamination, so that it will be possible to limit the matter even before the new technique is brought into use.

The paper offers a contribution to research on the different factors (temperature, container, micro-organisms, dose and irradiation conditions) affecting the preservation of fish, and to achieving the best possible conditions for realizing the great potentialities opened up by irradiation in the preservation of fisheries products.

Essais de radio-pasteurisation de filets de poissons frais et de harengs fumés conservés à differentes températures

Les essais de contrôle microbiologiques et physico-chimiques effectués sur deux cents échantillons de filets de poissons frais et harengs fumés salés et non salés montrent que l'irradiation, aux doses de 0,2 à 0,35 Mrad, améliore la qualité et triple ou quadruple la vie commerciale du poisson, à condition de le maintenir à une température de 0° à 1°C (32° à 34°F). Les échantillons irradiés aux mêmes doses, mais conservés à une température de 6° à 8°C (43° à 46°F), ont une vie commerciale doublée ou triplée. On a utilisé pour traiter les produits l'irradiateur mobile industriel I.R.M.A. avec source de ^{137}Cs (175.000 ci).

Les examens microbiologiques, avant et après irradiation, des échantillons ont confirmé l'efficacité de l'irradiation comme méthode de pasteurisation des filets de poisson. Ceux-ci sont fréquemment contaminés par des germes saprophites banaux, fécaux, et quelquefois pathogènes, qui proviennent des mains et des outils des utilisateurs. La microflore totale initiale, de 10^5 à 10^6 germes/g, est réduite par un facteur de 10^3 à 10^5, selon les doses.

La mise au point des milieux de cultures sélectifs ou non, sur lesquels ont été isolés, puis identifiés, de nombreux groupes de micro-organismes, a révélé que la flore dominante dans le poisson, constituée par *Achromobacter*, *Pseudomona*, est pratiquement éliminée aux doses de radio-pasteurisation. Seule reste une flore résiduelle, formée par des espèces résistant mieux à l'irradiation, telles que: levures, *Micrococcus*, *Sarcines* et *Bacillus*, la plupart saprophites banaux, qui se développent ensuite et se substituent à la flore initiale.

Selon l'origine du poisson ont été constatés différents équilibres quantitatifs de la flore bactérienne, alors que l'équilibre qualitatif reste stable.

Les résultats obtenus confirment, en général, ceux d'autres auteurs qui ont étudié la radio-pasteurisation du poisson. Des analyses détaillées de la microflore donnent une idée des sources de contamination, ce qui permettra, par la suite, de les limiter avant l'application de cette nouvelle méthode à la conservation des produits de la mer.

LAS nuevas tendencias de expansión comercial del pescado, en gran parte impulsadas por el incremento de la pesca en todo el mundo, han creado la necesidad de complementar y perfeccionar los métodos clásicos de su conservación con nuevos procedimientos y técnicas más avanzados.

La irradiación de filetes de pescado blanco fresco y de arenques ahumados puede considerarse un ejemplo de solución favorable, extensivo a otras variedades y tipos de pescado y mariscos e incluso a productos derivados. Las pruebas de radurización presentadas en este trabajo pretenden estudiar de forma práctica y realista el mejoramiento y prolongación de la vida comercial de varias especies de pescado aplicables en España a la merluza y pescadilla, así como también a los arenques ahumados con sal y sin ella.

MATERIAL Y METODOS

Las muestras de pescado tratadas por irradiación y analizadas fueron de varios orígenes que se especificarán en cada caso. Todas se irradiaron en la Unidad de Irradiación denominada I.R.M.A. situada en Saclay (Centro de Estudios Nucleares). Esta Unidad (fig 1) está constituida por una fuente de cesio-137 de una actividad actual de 175.000 ci con dispositivos de utilización industrial de la irradiación que permite la aplicación de dosis de 0,41 Mrad/h a las muestras situadas en el centro de los contenedores. Dicho irradiador es propiedad de la "Société Conservatome Industrie".

La irradiación de las muestras, se efectuó en cuatro grupos, cada uno de los cuales se considerará como una experiencia independiente aunque los resultados se discutirán en conjunto.

Técnicas generales

En todas las experiencias se aplicaron ciertas técnicas comunes con objeto de obtener resultados uniformes y significativos.

Durante el transporte el pescado fue introducido en bolsos isotermos rodeados de saquetes y botes refrigerantes de hielo, que aseguraron el mantenimiento de la temperatura de refrigeración de 0° a 1°C (32° a 34°F). Esta precaución también se observó durante la irradiación y en todo momento de la experiencia, controlándose diariamente la temperatura del refrigerador donde se conservaron las muestras.

Periódicamente una o dos veces por semana, según la experiencia, se efectuaron los análisis y observaciones de control que comprendieron los siguientes exámenes:

(1) Exámenes bacteriológicos:

—Microflora aerobia/anaerobia mesófila total.
A C Medium y agua de peptona como diluyente.
Incubación a 30°C (86°F) durante 72 h.

—Coliformes.
Medio DPTS (desoxicolato sódico).
Incubación a 37°C (99°F) durante 24 h.

—*Escherichia Coli*, tipo I.
Fermentación lactosa y producción de gas. Prueba de Mackenzie con agua de peptona y verde brillante con campana.
Incubación a 44°C (111°F) durante 48 h.

—*Microccocus* patógenos.
Método de Baird Parker.
Incubación a 37°C durante 24 h.

—*Clostridium* sulfito reductores, tipo Welchii *perfringens*.
Incubación a 44°C durante 24 h.

—Investigación de Enterobacteriáceas patógenas, principalmente *Salmonella*. Medio de enriquecimiento de selenita cistina durante 16 h a 44°C y resiembra en verde brillante a 37°C durante 24 h. En caso positivo volver a sembrar en medios selectivos las colonias formadas sometiéndolas a pruebas bioquímicas y serológicas.

(2) Exámenes físico-químicos:

Se efectuaron las siguientes determinaciones:

—Caracteres organolépticos: color, estructura, olor y sabor.

—Medida del pH por medio de peachímetro de precisión de 0,01.

—Valoración de Nitrógeno Básico Volátil Total (NBVT).

Todas estas técnicas de control higiénico están inspiradas en los protocolos oficiales de los Laboratorios Centrales de los Servicios Veterinarios de la Región de París.

En la tercera experiencia, de confirmación de resultados, se aplicaron otros métodos de recuento de gérmenes, basados en las técnicas de microbiología alimentaria del Instituto Pasteur de Lille y en los estudios efectuados por los investigadores del Laboratorio de Microbiología del Centro Nacional de Investigaciones Zootécnicas (C.N.R.Z.).

Fig 1. Unidad de Irradiación I.R.M.A. 400/1. Vista general mostrando su disposición de marcha en remolque

Aplicación de las técnicas microbiológicas

(1) Recogida de muestras.

Teniendo en cuenta que los filetes de pescado presentan una contaminación de la superficie que normalmente tiene más importancia que la contaminación interior de procedencia visceral, la recogida de muestras se efectuó marcando, en condiciones asépticas, un rectángulo sobre cada filete, de 10 cm^2 (2,5×4 cm^2) y extrayéndolo en forma de película de unos 2 mm. Como su peso resultó ser de unos 4 g se pudo calcular al mismo tiempo el número de gérmenes por cm^2 y por g, de acuerdo con la técnica de dilución decimal empleada.

Las muestras se trituraron y homogeneizaron mediante un ultra-turrax sobre el medio de dilución contenido en un frasco según se describirá a continuación.

(2) Dilución y siembra.

Cada muestra de 4 g se introduce en un frasco de 120 ml de boca ancha provisto de tapón metálico a rosca conteniendo 36 ml del medio diluyente cuya composición centesimal es: 0,5 g de extracto de carne, 0,5 de peptona, 1 g de triptona, pH 7. Cuando se investigaron gérmenes de más difícil crecimiento se empleó un medio diluyente de enriquecimiento compuesto de: 1,5 g de peptona, 0,5 g de extracto de levadura, 0,5 g de sal (NaCl), 0,5 g de glucosa y agua destilada hasta 100 ml.

Las siembras se efectuaron en aerobiosis sobre placas de Petri, en condiciones anaerobias en tubos largos de 8×420 mm, y para los gérmenes aerobios y anaerobios en tubos de ensayo de 16×160 mm.

(3) Medios de cultivo.

Los medios elegidos fueron muy variados; en la imposibilidad de describirlos todos, sólo se indicarán los que suponen alguna innovación sobre los medios clásicos.

—Para la investigación del SH_2 y del indol:

Agua de peptona

Composición:

Peptona	15 g
NaCl	5 g
Citrato de hierro	0,5 g
Cistina	0,2 g
Agua destilada	1 litro
pH	7

Hay que incubar 24–48 h los tubos sembrados y adicionar después el reactivo de Erlich–Kovacs. Sustituye con ventaja los anteriores métodos a base de tiras de papel con acetato de plomo.

—Para recuento de los *Micrococcus:*

Medio de Baird–Parker.

Se ha modificado la técnica de siembra en este medio de la forma siguiente:

Los inhibidores, piruvato, glicina y telurito y la yema de huevo se colocan en contacto durante cinco minutos a 37°C en un tubo intermedio conteniendo la dilución, agregando después el medio base de agar (15 ml) de Baird–Parker, vertiéndolo seguidamente sobre la placa de Petri.

Este medio se incuba en aerobiosis a 37°C de 24 a 36 h. El recuento de *Micrococcus* patógenos se realiza con mayor probabilidad que con los otros medios (Chapman, etc.).

—Para la numeración de la microflora total:

(a) A C Medium—Modificado.

Este medio forma parte de los protocolos oficiales y es de gran utilidad por permitir el recuento de gérmenes aerobios y anaerobios, debido a su especial composición con ácido ascórbico junto a los demás productos. Su estado semilíquido facilita la numeración de los gérmenes en el mismo tubo de ensayo, ya que las colonias aparecen a los tres días de incubación a 30°C (86°F) en forma de largos husos.

Su constitución está indicada en la fórmula "Difco" B–316, a la que hay que agregar:

Extracto de malta	3 g
Cistina	0,2 g
Indicador de Andrade	10 cc

Cuando no es posible retrasar por más tiempo de las 72 h la lectura de resultados, este medio puede sustituir los medios de agar nutritivo en placas de Petri que requieren seis días de incubación.

(b) Medio de agar nutritivo

Composición centesimal:

Triptona	0,5 g
Extracto de carne	1,5 g
Glucosa	0,5 g
Púrpura de bromocresol	0,002 g
Agar	2,0 g

El pH es de 7,4 antes de esterilizar al autoclave.

Este medio se incuba en aerobiosis y anaerobiosis a 22° y a 37°C (72° y a 99°F) durante seis días.

—Para la determinación de los *Streptococcus:*

Se emplea el mismo medio que el anterior, pero cambiando el pH a 5,4, suprimiendo el colorante y con la glucosa a 0,1 g por ciento. En el momento del empleo se añade una solución acuosa de parabenzoquinona (PBQ) al 0,6 por ciento en la cantidad de 0,5 ml por tubo.

—Para las levaduras y hongos microscópicos:

El mismo medio de agar que el de la flora total, pero con un pH ajustado a 3,8. Para la preparación de este medio se esterilizan al autoclave separadamente el caldo nutritivo a pH 3,8 y el agar. La mezcla se efectúa al momento de ponerlo en la placa de Petri. Se incuba en aerobiosis durante seis días.

—Para los coliformes (*Escherichia, Pseudomonas* y otros Gram negativos):

Medio DPTS (desoxicolato sódico).

Composición centesimal:

Desoxicolato de sodio (Difco)	0,1 g
Peptona	1,5 g
Triptona (Difco)	1,0 g
Safranina	0,002 g
pH	7,4–7,5

Este medio se incuba en aerobiosis y anaerobiosis durante seis días.

Técnicas físico-químicas. La evolución físico-química del pescado ha sido estudiada, como se indicó anteriormente por tres grupos de exámenes: organolépticos, pH y valoración del nitrógeno básico volátil total.

(a) Caracteres organolépticos.

Para destacar el olor, las muestras de pescado fueron introducidas en frascos cerrados, sometidos durante 5 min a ebullición y después destapados.

Para apreciar el sabor se hicieron pruebas de degustación del pescado cocido y frito.

(b) pH.

Cinco gramos de pescado fueron triturados y mezclados íntimamente con 5 ml de agua destilada. Se hicieron las determinaciones por duplicado.

(c) Nitrógeno Básico Volátil Total.

En estas valoraciones se siguió el protocolo operatorio del Laboratorio Central de los Servicios Veterinarios antes mencionados que nos da el resultado expresado en mg/100 g de pescado.

Los exámenes microbiológicos y físico-químicos se realizaron en colaboración con el Laboratorio de los Servicios Veterinarios de Vaugirard, en los laboratorios de microbiología del Departamento de Radioelementos del Centro de Estudios Nucleares de Saclay y en el Laboratorio de Microbiología Alimentaria del C.N.R.Z. de Jouy en Josas (Francia).

Experiencia preliminar: Irradiación de pescado fresco *Gadus merlangus*

El objeto de esta experiencia fue poner a punto las técnicas de control del estado fresco del pescado, conocer la carga microbiana inicial y comprobar el desarrollo de la microflora después de irradiado.

CUADRO 1. IRRADIACIÓN DE FILETES DE PESCADO (*Gadus merlangus*); RESULTADOS MICROBIOLÓGICOS Y ORGANOLÉPTICOS (Conservación a 0°/+1°C)

N°	Fecha	Dosis	SH_2	Indol	E.Coli I Ferment. lactosa	Clostridium Sulfito reduct.	Salmonella Kaufman	Micrococcus Baird Parker	Coliformes Desoxycolato	Flora total AC Medium(1)	Caracteres organolépticos
1	Inicial	Testigo	7	5	0 0 0	0	Estéril	<100	8.000/g	2×10^6	Regulares
2	"	"	7	5	0 0 0	0	"	<100	7.000/g	3×10^6	"
3	7° día	Testigo	7	0	0 0 0	0	Estéril	<100	10^4	2×10^7	Inaceptables
4	"	100.000 rad	5	0	0 0 0	0	"	<100	10^3	1×10^6	Regulares
5	"	200.000 "	4	0	0 0 0	0	"	<100	10^2	1×10^6	Aceptables
6	"	275.000 "	3	0	0 0 0	0	"	<100	10^2	1×10^5	"
7	"	350.000 "	1	0	0 0 0	0	"	<100	10^2	1×10^4	Buenos
8	14° día	Testigo	8	7	0 0 0	0	Colonias pseudomo;	<100	10^5	1×10^9	Inaceptables
9	"	100.000 rad	6	3	0 0 0	0	Estéril	<100	$1{,}6 \times 10^3$	2×10^7	"
10	"	200.000 "	3	1	0 0 0	0	"	<100	10^2	1×10^6	Regulares
11	"	275.000 "	1	0	0 0 0	0	"	<100	10	1×10^5	Aceptables
12	"	350.000 "	1	0	0 0 0	0	"	<100	10	1×10^4	"
13	21° día	Testigo	7	6	0 0 0	0	Colonias verdes	<100	8×10^5	$>1 \times 10^9$	Inaceptables
14	"	100.000 rad	5	3	0 0 0	0	Estéril	<100	$1{,}5 \times 10^4$	1×10^8	"
15	"	200.000 "	3	0	0 0 0	0	"	<100	10^3	1×10^6	Regulares
16	"	275.000 "	2	0	0 0 0	0	"	<100	10^2	1×10^5	"
17	"	350.000 "	1	0	0 0 0	0	"	<100	10	1×10^4	Aceptables

(1) Número de gérmenes/g

Estas pruebas preliminares hiciéronse con 4 kg de filetes de dicha especie de pescado fresco, adquirido en el Mercado Central de París, envuelto en trozos de hielo.

Repartido en porciones de 225 g y envasado en láminas de plástico con envoltura comercial, recibió el siguiente tratamiento de irradiación:

3 paquetes	150.000 rad
3 paquetes	200.000 rad
3 paquetes	275.000 rad
3 paquetes	350.000 rad
3 paquetes	no se irradiaron conservándose como testigo

Temperatura de conservación: 0° a 1°C (32° a 34°F).

Al día siguiente se efectuaron los análisis de partida en muestras testigo e irradiadas a las diferentes dosis. A los días 7, 14 y 21 se repitieron los análisis y observaciones. Los resultados se detallan en el Cuadro 1 y en la gráfica correspondiente (fig 2).

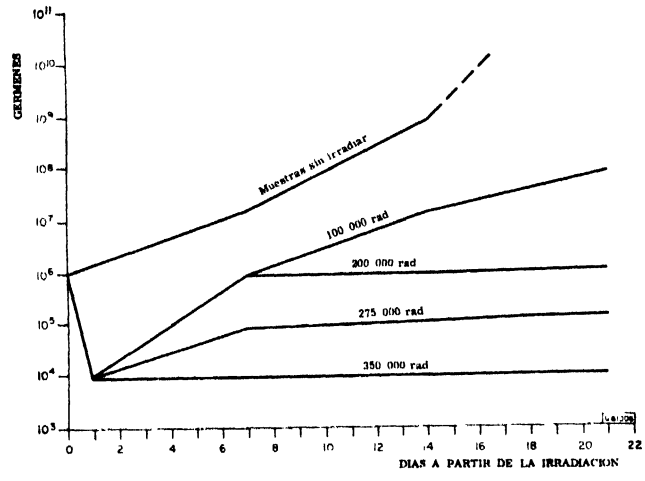


Fig 2. Desarrollo de la microflora en filetes de Gadus merlangus

Interpretación de resultados de la primera experiencia. De los datos obtenidos mediante los diversos análisis bacteriológicos puede deducirse que el pescado testigo presentó una carga microbiana del orden de 10^6 gérmenes/g como flora total inicial y que ésta se elevó rápida y considerablemente en la primera semana a 10^7, para alcanzar en la segunda semana 10^9 gérmenes/g. En

contraste, las muestras irradiadas, analizadas por pruebas rápidas de recuento directo al microscopio teñidas con azul de metileno y Gram, y por la técnica de dilución decimal con agua de peptona y A C Medium, resultaron con una flora total de 10 gérmenes/g a las 24 h después de la irradiación. Transcurrida la primera semana este número se elevó a 10^6 gérmenes/g en la tratada con 100.000 y 200.000 rad; a 10^5 en la de 275.000 rad y a 10 en la de 350.000 rad. Estos números no variaron sensiblemente durante las dos semanas siguientes que duró la experiencia.

Estos resultados nos orientan que las dosis más recomendables para aplicar al pescado fresco con fines de conservación varían entre 200.000 y 300.000 rad.

Experiencia de irradiación de filetes de pescado *Gadus aeglefinus*

Procedentes de Boulogne-sur-mer se recibieron 20 kg (44 lb) de filetes de pescado de la especie *Gadus aeglefinus* en cajas de madera rodeados de hielo y envueltos en cubiertas plásticas.

De la misma forma que en las pruebas preliminares, el

CUADRO 2. IRRADIACIÓN DE FILETES DE PESCADO (*Gadus aeglefinus*); RESULTADOS MICROBIOLÓGICOS Y FÍSICO-QUÍMICOS (Conservación a 0°/+1°C)

Nº	Fecha	Dosis rad	SH_2	Indol	E.Coli I	Clostridium	Salmonella	Micrococcus	Coliformes (1)	Flora total (1)	pH	N BVT (2)	Car. org. *
1	6° día	Testigo	7	5	0	0	Estéril	<100/g	2×10^5	2×10^8	6,9	35	I
2	"	100.000	0	3	0	0	"	<100 "	1×10^2	1×10^6	6,55	28,6	R
3	"	200.000	0	2	0	0	"	<100 "	1×10	5×10^5	6,65	20,5	N
4	"	250.000	0	0	0	0	"	<100 "	1×10	1×10^5	6,40	18,3	N
5	"	350.000	0	0	0	0	"	<100	ninguno	1×10^4	6,28	15,5	N
6	9° día	Testigo	8	6	0	0	Colonias verdes	<100 "	$1,2 \times 10^4$	5×10^8	7,1	76,5	I
7	"	100.000	4	1	0	0	Estéril	<100 "	5×10^2	2×10^6	6,8	31,4	I
8	"	200.000	3	0	0	0	"	<100 "	10	2×10^5	6,5	26,2	N
9	"	250.000	2	0	0	0	"	<100 "	10	3×10^5	6,0	23,5	N
10	"	350.000	1	0	0	0	"	<100 "	ninguno	5×10^4	6,2	21,8	N
11	13° día	Testigo	8	7	1	0	Colonias verdes	<100 "	$2,5 \times 10^5$	1×10^9	7,1	158,5	I
12	"	100.000	3	1	0	0	Estéril	<100 "	$1,8 \times 10^3$	5×10^6	6,6	35,7	I
13	"	200.000	2	0	0	0	"	<100 "	100	3×10^5	6,5	30,5	N
14	"	250.000	2	0	0	0	"	<100 "	10	1×10^5	6,3	32,2	N
15	"	350.000	1	0	0	0	"	<100 "	ninguno	7×10^4	6,3	30,1	N
16	16° día	Testigo	8	6	1	0	Colonias verdes	<100 "	$2,8 \times 10^5$	>1 x 10^9	7,2	172,4	I
17	"	100.000	4	1	0	0	Estéril	<100 "	1×10^3	4×10^7	6,9	53,2	I
18	"	200.000	3	1	0	0	"	<100 "	5×10^2	2×10^6	6,5	32,1	R
19	"	250.000	2	1	0	0	"	<100 "	1×10^2	3×10^5	6,6	27,2	N
20	"	350.000	1	0	0	0	"	<100 "	ninguno	1×10^5	6,4	28,5	N
21	20° día	Testigo	8	7	1	0	Colonias verdes	<100	5×10^5	>1 x 10^9	7,1	180	I
22	"	100.000	4	1	0	0	Estéril	<100	2×10^3	5×10^8	7,0	61,4	I
23	"	200.000	2	1	0	0	"	<100	1×10^3	5×10^6	6,7	35,7	I
24	"	250.000	3	1	0	0	"	<100	1×10^3	1×10^6	6,5	43,2	R
25	"	350.000	1	0	0	0	"	<100	1×10^2	1×10^5	6,3	25,5	N
26	23° día	Testigo	8	7	1	0	Colonias verdes	<100	8×10^5	>1 x 10^9	7,2	180,0	I
27	"	100.000	6	2	1	0	"	<100	3×10^4	8×10^8	7,0	76,2	I
28	"	200.000	2	1	0	0	Estéril	<100	2×10^3	1×10^6	6,6	57,1	I
29	"	250.000	2	1	0	0	"	<100	1×10^3	7×10^5	6,3	35,7	N
30	"	350.000	1	0	0	0	"	<100	5×10^2	1×10^5	6,5	30,5	N
31	28° día	Testigo	8	7	1	0	Colonias verdes	<100	8×10^5	>1 x 10^9	7,1	180,0	I
32	"	100.000	5	2	1	0	"	<100	5×10^4	5×10^8	7,1	85,5	I
33	"	200.000	3	1	0	0	Estéril	<100	3×10^3	1×10^6	6,5	52,3	I
34	"	250.000	2	1	0	0	"	<100	1×10^3	1×10^6	6,3	36,6	R
35	"	350.000	1	1	0	0	"	<100	4×10^2	5×10^5	6,4	28,5	N
36	31° día	Testigo	8	7	1	0	Colonias verdes	<100	8×10^5	>1 x 10^9	7,2	180,0	I
37	"	100.000	6	3	1	0	"	<100	4×10^4	5×10^8	7,1	97,6	I
38	"	200.000	4	2	0	0	Estéril	<100	1×10^4	5×10^7	7,0	68,5	I
39	"	250.000	3	1	0	0	"	<100	5×10^3	5×10^6	6,7	41,2	R
40	"	350.000	1	1	0	0	"	<100	1×10^3	6×10^5	6,5	25,8	N

* N = Normal; R = Regular; I = Inaceptable
(1) Número de gérmenes/g = Número de gérmenes/cm^2 x 4 x 10
(2) mg/100 g pescado

pescado fresco se repartió en paquetes de 225 g (0.5 lb) envueltos en plástico comercialmente, haciendo un total de 80 muestras.

Tratamiento:

16 paquetes	100.000 rad
16 paquetes	200.000 rad
16 paquetes	250.000 rad
16 paquetes	350.000 rad

16 paquetes no se irradiaron (testigo)

Ocho muestras de cada uno de estos grupos se conservaron a 0°/1°C y las restantes se mantuvieron a temperatura de 6/8°C (43/46°F) durante los 30 días que duró la experiencia.

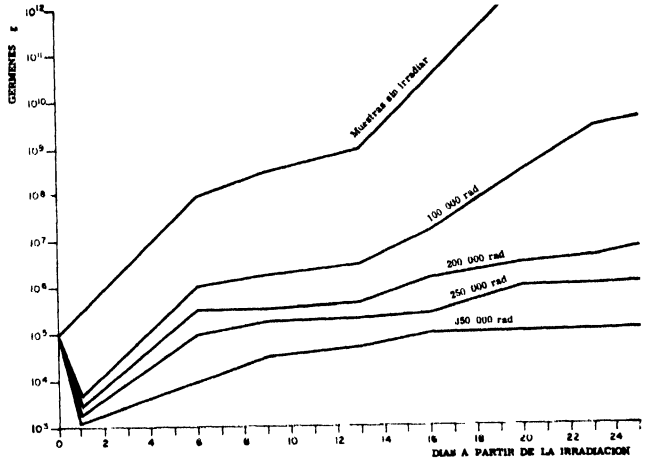


Fig 3. Desarrollo de la microflora total en filetes de Gadus aeglefinus. *Temperatura de conservacion 0°/+1°C*

Además de las técnicas indicadas generales, se aplicaron otros métodos rápidos para la determinación de la flora inicial, en dos muestras testigo y a las 24 h post-irradiación, que consistieron en recuentos directos al microscopio y contajes por el método decimal de dilución con agua de peptona adicionada de citrato de hierro y A C Medium. Estos resultados se reflejan en la fig 3 junto con los demás datos que se detallan en el Cuadro 2.

Interpretación de los resultados. De las 80 muestras analizadas, cuyos datos se reflejan en las figs 3, 4, 5 y 6 y en los Cuadros 2 y 3, podemos extraer interesantes

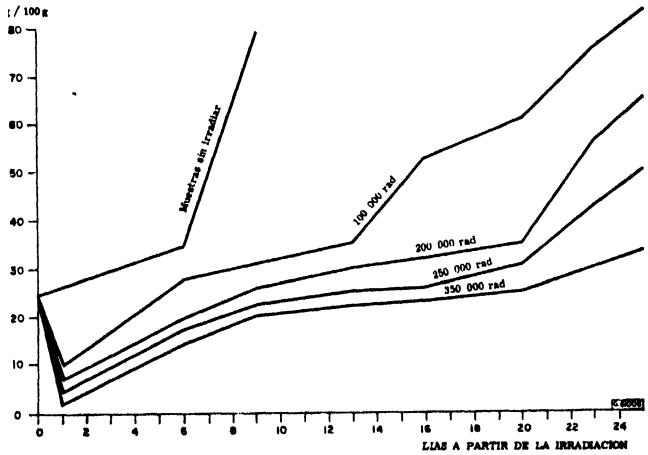


Fig 4. Evolución del nitrógeno básico volátil total en filetes de Gadus *aeglefinus. Temperatura de 0°/+1°C*

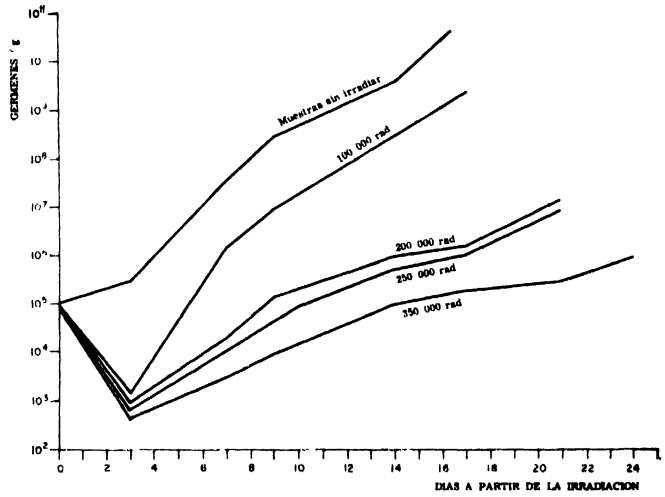


Fig 5. Desarrollo de la microflora en filetes de Gadus aeglefinus. *Temperatura de conservación +6°/+8°C*

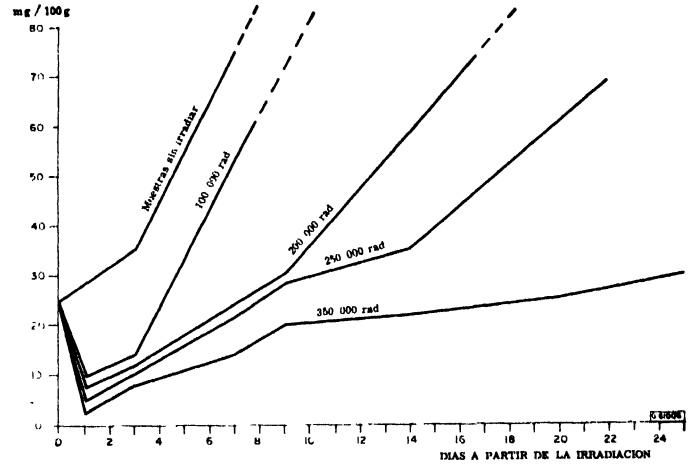


Fig 6. Evolución del nitrógeno básico volátil total en filetes de Gadus aeglefinus. *Temperatura +6°/+8°C*

enseñanzas sobre la evolución microbiológica y físico-química de los filetes de pescado fresco, irradiado y conservado a diferentes temperaturas. De acuerdo con la finalidad de esta experiencia, ha quedado bien patente la importancia y necesidad de conservar el pescado a bajas temperaturas de refrigeración para que los resultados de la irradiación sean más ventajosos.

Los análisis de partida de las muestras testigo, expresados en gérmenes/g dieron un número de 10^5. Como consecuencia del efecto de la irradiación este número descendió a las 24 h a 10^3 para elevarse mucho más rápidamente a 10^8 y a 10^9 en las muestras irradiadas con 100.000 rad que fueron conservadas a 6/8°C. Las muestras irradiadas con 200.000 y 250.000 rad no pasaron de 10^7 y las irradiadas con 350.000 rad no sobrepasaron los 10^5 gérmenes/g conservadas a 0°/1°C, mientras que las almacenadas a 6/8°C alcanzaron 10^6 gérmenes/g.

Estos datos microbiológicos se corresponden estrechamente con los datos físico-químicos de la determinación del pH y de la valoración del nitrógeno básico volátil total.

Merece destacarse el hecho de las reducidas cifras de gérmenes coliformes en los dos grupos de muestras conservadas a diferentes temperaturas. El número tan

CUADRO 3. IRRADIACIÓN DE FILETES DE PESCADO (*Gadus aeglefinus*); RESULTADOS MICROBIOLÓGICOS Y FÍSICO-QUÍMICOS
(Conservación a +6°/+8°C)

Nº	Fecha	Dosis rad	SH_2	Indol	E.Coli I	Clostridium	Salmonella	Micrococcus	Coliformes (1)	Flora total (1)	pH	N BVT (2)	Car. org. *
1	3° día	Testigo	3	2	0	0	Estéril	<100	2×10^3	5×10^5	6,7	30,55	I
2	"	100.000	1	0	0	0	"	<100	2×10^2	2×10^3	6,5	14,67	N
3	"	200.000	0	0	0	0	"	<100	$<1 \times 10^2$	10^3	6,5	12,40	N
4	"	250.000	0	0	0	0	"	<100	< 100	10^3	6,4	12,00	N
5	"	350.000	0	0	0	0	"	<100	<100	10^3	6,2	10,50	N
6	7° día	Testigo	7	5	1	0	Colonias verdes	<100	$2,8 \times 10^4$	6×10^7	7,0	75,85	I
7	"	100.000	2	2	0	0	"	<100	3×10^3	2×10^6	6,9	50,30	I
8	"	200.000	0	0	0	0	Estéril	<100	<100	3×10^4	6,4	24,50	N
9	"	250.000	0	0	0	0	"	<100	<100	4×10^4	6,5	25,64	N
10	"	350.000	0	0	0	0	"	<100	<100	5×10^3	6,2	14,77	N
11	9° día	Testigo	8	6	1	0	Colonias verdes y rojas	<100	8×10^4	5×10^8	7,1	120,34	I
12	"	100.000	3	2	1	0	"	<100	5×10^3	10^7	7,0	88,65	I
13	"	200.000	2	0	0	0	Estéril	<100	3×10^2	2×10^5	6,7	30,05	R
14	"	250.000	1	0	0	0	"	<100	<100	10^5	6,4	28,36	N
15	"	350.000	0	0	0	0	"	<100	100	10^4	6,5	25,42	N
16	14° día	Testigo	9	6	1	0	Colonias verdes y rojas	<100	2×10^5	6×10^9	7,2	200,00	I
17	"	100.000	4	3	1	0	"	<100	4×10^4	5×10^8	7,0	120,54	I
18	"	200.000	3	1	0	0	Estéril	<100	5×10^3	10^6	6,8	58,66	I
19	"	250.000	2	2	0	0	"	<100	10^3	10^6	6,6	30,46	R
20	"	350.000	0	0	0	0	"	<100	2×10^2	10^5	6,4	22,30	N
21	17° día	Testigo	-	-	-	-	-	-	-	-	-	-	-
22	"	100.000	5	3	1	0	Colonias verdes	<100	10^5	5×10^9	7,1	200,00	I
23	"	200.000	3	2	1	0	"	<100	3×10^4	4×10^9	6,9	87,56	I
24	"	250.000	3	1	1	0	"	<100	10^4	2×10^6	6,9	67,35	I
25	"	350.000	1	0	0	0	Estéril	<100	10^3	3×10^5	6,5	22,30	N
26	21° día	Testigo	-	-	-	-	-	-	-	-	-	-	-
27	"	100.000	-	-	-	-	-	-	-	-	-	-	-
28	"	200.000	4	2	0	0	Estéril	<100	2×10^4	4×10^7	6,9	115,50	I
29	"	250.000	2	1	0	0	"	<100	10^4	2×10^7	6,9	98,30	I
30	"	350.000	1	0	0	0	"	<100	10^3	5×10^5	6,6	25,05	N
31	24° día	Testigo	-	-	-	-	-	-	-	-	-	-	-
32	"	100.000	-	-	-	-	-	-	-	-	-	-	-
33	"	200.000	-	-	-	-	-	-	-	-	-	-	-
34	"	250.000	-	-	-	-	-	-	-	-	-	-	-
35	"	350.000	1	0	0	0	Estéril	<100	2×10^3	7×10^5	6,5	24,56	N
36	31° día	Testigo	-	-	-	-	-	-	-	-	-	-	-
37	"	100.000	-	-	-	-	-	-	-	-	-	-	-
38	"	200.000	-	-	-	-	-	-	-	-	-	-	-
39	"	250.000	-	-	-	-	-	-	-	-	-	-	-
40	"	350.000	1	0	0	0	Estéril	<100	10^4	5×10^6	6,8	35,95	R

* N = Normal; R = Regular; I = Inaceptable
(1) Número de gérmenes/g = Número de gérmenes/cm^2 x 4 x 10
(2) mg/100 g pescado

reducido de este tipo de gérmenes nos indica la buena calidad del pescado desde su recepción así como el efecto bactericida de la irradiación sobre los gérmenes de origen fecal.

Pruebas de confirmación con filetes de pescado *Gadus callarias*

Con objeto de comprobar los efectos de la irradiación sobre le flora inicial y el desarrollo ulterior de los gérmenes residuales, se efectuó una tercera experiencia con otra especie de pescado adquirido en el Mercado Central de París.

Envueltos los filetes de pescado en forma comercial como en las experiencias anteriores fueron transportados al Centro de Irradiación donde recibieron las siguientes dosis:

4 muestras de 200 g (7 oz) 200.000 rad
4 muestras de 200 g (7 oz) 350.000 rad
4 muestras de 200 g (7 oz) no recibieron irradiación (testigo).

Los resultados obtenidos se indican en el Cuadro 4 y figs 7 y 8.

En estos análisis se aplicaron las mismas técnicas generales, pero además se efectuaron investigaciones para

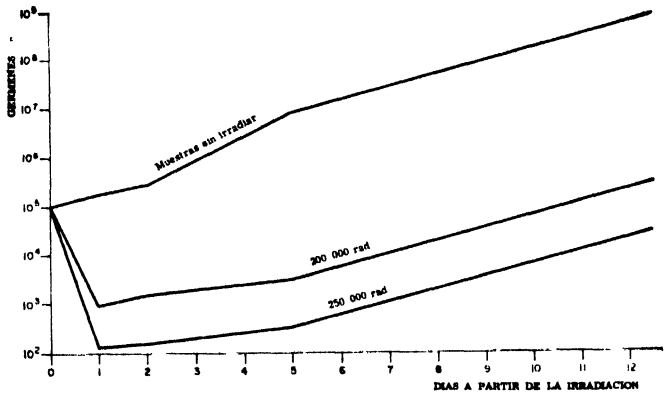


Fig 7. Desarrollo de la microflora total en filetes de Gadus callarias. *Temperatura de conservación 0°/+1°C*

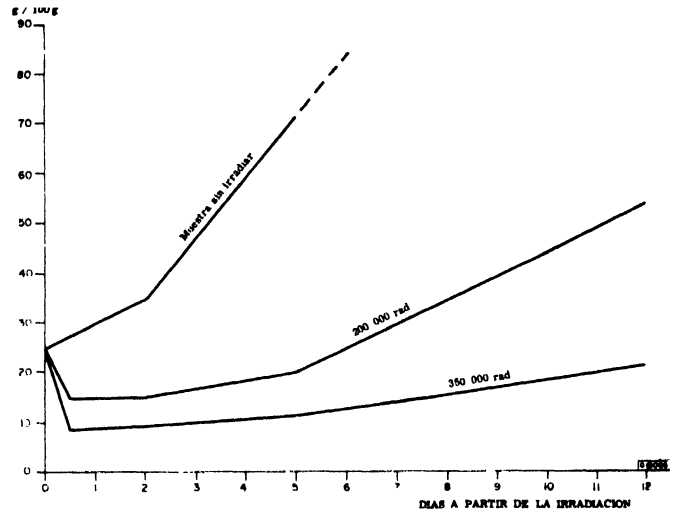


Fig 8. Evolución del nitrógeno básico volátil total en filetes Gadus callarias. *Temperatura 0°/+1°C*

determinar cualitativa y cuantitativamente el desarrollo de la microflora residual empleando los medios de cultivo selectivos, con sus correspondientes inhibidores siguiendo la pauta y normas técnicas del Laboratorio de Microbiología Alimentaria del Centro Nacional de Investigaciones Zootécnicas (C.N.R.Z.). A los 19 días post-irradiación se recogieron y analizaron tres muestras: una testigo y las otras dos irradiadas, a diferentes dosis.

De acuerdo con las técnicas generales, y después de efectuar la trituración, homogeneización y dilución de las muestras, se sembraron en los distintos medios de cultivo con arreglo a sistemática apropiada.

Los medios de cultivo han sido los indicados en las técnicas generales y los inhibidores agregados a los medios de agar nutritivos fueron:

(1) Acido de sodio y trifeniltetrazolio en solución de 0,15 por ciento: 0,5 ml por tubo de agar.

(2) Parabenzoquinona en solución de 0,6 por ciento: 0,5 ml por tubo de agar.

(3) Naranja de acridina en solución de 0,03 por ciento: 0,2 ml por tubo de agar.

La lectura de estas siembras una vez transcurridos los períodos de incubación correspondientes confirmaron los datos obtenidos con los métodos que se expresan en el Cuadro 4 y figs 7 y 8. Quedó además precisada la composición cualitativa y cuantitativa de la flora residual, siendo interesante destacar el hecho de que los microorganismos de las muestras irradiadas cultivados en aerobiosis resultaron ser en su inmensa mayoría Gram negativos, ya que dieron un número aproximadamente igual en las placas de Petri con agar nutritivo para la flora total que en las placas sembradas en medio a base de desoxicolato inhibidor de los Gram positivos. En anaerobiosis, se apreció en las muestras tratadas con la irradiación, una abundancia de *Lactobacillus* que se pudieron contar hasta un número de 138 en la muestra de 200 krad en la dilución −3. En esta misma muestra el número de colonias de levaduras fué de 5 en la dilución −2. Teniendo en cuenta que la conservación del pescado irradiado era de casi tres semanas después del tratamiento, tenemos que interpretar que los gérmenes existentes proceden de las cepas más radiorresistentes, siempre que se cuente con la imposibilidad de una recontaminación.

CUADRO 4. IRRADIACIÓN DE FILETES DE PESCADO (*Gadus callarias*); RESULTADOS MICROBIOLÓGICOS Y FÍSICO-QUÍMICOS (Conservación a 0°/+1°C)

Nº	Fecha	Dosis rad	SH_2	Indol	E.Coli I	Clostridium	Salmonella	Micrococcus	Coliformes (1)	Flora total (1)	pH	N BVT (2)	Car. org. *
1	Inicial	Testigo	0	0	0	0	0	<100	2×10^2	1×10^5	6,6	26,55	N
2	1er día	200.000	0	0	0	0	0	<100	1×10	1×10^3	6,3	15,80	N
3	"	350.000	0	0	0	0	0	<100	ninguno	1×10^2	5,6	8,75	N
4	2º día	Testigo	1	0	0	0	0	<100	3×10^3	5×10^5	6,8	35,60	R
5	"	200.000	0	0	0	0	0	<100	1×10	2×10^3	6,2	14,95	N
6	"	350.000	0	0	0	0	0	<100	ninguno	1×10^2	5,5	9,45	N
7	5º día	Testigo	2	1	0	0	0	<100	5×10^4	1×10^7	7,0	72,50	I
8	"	200.000	0	0	0	0	0	<100	4×10	5×10^3	6,4	20,35	N
9	"	350.000	0	0	0	0	0	<100	ninguno	5×10^2	6,1	12,70	N
10	13º día	Testigo	7	5	0	0	0	<100	6×10^5	1×10^9	7,2	178,33	I
11	"	200.000	1	0	0	0	0	<100	1×10^2	5×10^5	6,9	54,20	R
12	"	350.000	0	0	0	0	0	<100	1×10	5×10^4	6,4	21,15	N

* N = Normal; R = Regular; I = Inaceptable
(1) Número de gérmenes/g = Número de gérmenes/cm^2 x 4 x 10
(2) mg/100 g pescado

CUADRO 5. IRRADIACIÓN DE ARENQUES AHUMADOS SALADOS (*Clupea harengus*); RESULTADOS MICROBIOLÓGICOS Y FÍSICO-QUÍMICOS (Conservación a 0°/+4°C)

Nº	Fecha	Dosis rad	SH_2	Indol	E.Coli I	Clostridium	Salmonella	Micrococcus	Coliformes (1)	Flora total (1)	pH	N BVT (2)	Car. org.*
1	Inicial	Testigo	1	0	0	0	Estéril	<100	10^2	4×10^2	6,3	16,50	N
2	3er día	100.000	0	0	0	0	"	<100	ninguno	10^2	6,2	11,35	N
3	"	200.000	0	0	0	0	"	<100	"	10^2	6,2	10,48	N
4	"	350.000	0	0	0	0	"	<100	"	10^2	6,1	9,68	N
5	"	600.000	0	0	0	0	"	<100	"	$<10^2$	5,8	9,05	N
6	"	2.500.000	0	0	0	0	"	<100	"	$<10^2$	5,6	7,98	N
7	10°día	Testigo	1	1	0	0	Estéril	<100	10^2	4×10^3	6,3	17,50	N
8	"	100.000	0	0	0	0	"	<100	ninguno	10^2	6,2	11,55	N
9	"	200.000	0	0	0	0	"	<100	"	10^2	6,2	10,30	N
10	"	350.000	0	0	0	0	"	<100	"	10^2	6,1	9,55	N
11	"	-	-	-	-	-	-	-	-	-	-	-	-
12	17°día	Testigo	1	1	0	0	Estéril	<100	10^2	5×10^4	6,5	17,50	N
13	"	100.000	0	0	0	0	"	<100	ninguno	10^2	6,3	10,86	N
14	"	200.000	0	0	0	0	"	<100	"	10^2	6,2	11,38	N
15	"	350.000	0	0	0	0	"	<100	"	10^2	6,2	10,35	N
16	"	600.000	0	0	0	0	"	<100	"	$<10^2$	5,7	9,47	N
17	24°día	Testigo	2	1	0	0	Estéril	<100	10^2	6×10^4	6,5	24,00	N
18	"	100.000	0	0	0	0	"	<100	ninguno	10^3	6,4	13,57	N
19	"	200.000	0	0	0	0	"	<100	"	10^2	6,4	10,55	N
20	"	350.000	0	0	0	0	"	<100	"	10^2	6,2	11,20	N
21	"	2.500.000	0	0	0	0	"	<100	"	$<10^2$	5,6	9,75	N
22	28°día	Testigo	2	1	0	0	Estéril	<100	10^2	5×10^4	6,7	26,57	N
23	"	100.000	1	0	0	0	"	<100	10^2	10^3	6,5	23,70	N
24	"	200.000	1	0	0	0	"	<100	10^2	10^3	6,4	18,30	N
25	"	350.000	0	0	0	0	"	<100	ninguno	10^2	6,4	12,48	N
26	"	600.000	0	0	0	0	"	<100	"	$<10^2$	5,8	10,65	N
27	35°día	Testigo	2	1	0	0	Estéril	<100	10^2	7×10^4	6,6	24,50	N
28	"	100.000	1	0	0	0	"	<100	10^2	10^3	6,4	22,75	N
29	"	200.000	1	0	0	0	"	<100	10^2	10^3	6,4	15,25	N
30	"	350.000	0	0	0	0	"	<100	ninguno	10^3	6,3	14,20	N
31	"	2.500.000	0	0	0	0	"	<100	"	$<10^2$	5,6	9,50	N
32	42°día	Testigo	3	1	0	0	Colonias verdes	<100	10^3	2×10^5	6,8	35,00	R
33	"	100.000	2	0	0	0	Estéril	<100	10^2	10^4	6,5	23,40	R
34	"	200.000	1	0	0	0	"	<100	10^2	10^3	6,4	18,35	N
35	"	350.000	1	0	0	0	"	<100	ninguno	10^3	6,4	15,50	N
36	"	600.000	0	0	0	0	"	<100	"	$<10^2$	5,9	10,60	N
37	50°día	Testigo	3	2	0	0	Colonias verdes	<100	10^4	6×10^5	6,9	40,20	R
38	"	100.000	1	1	0	0	Estéril	<100	10^3	3×10^4	6,6	24,32	R
39	"	200.000	1	1	0	0	"	<100	10^2	10^4	6,5	20,55	N
40	"	350.000	0	0	0	0	"	<100	ninguno	10^4	6,4	16,70	N

* N = Normal; R = Regular; I = Inaceptable
(1) Número de gérmenes/g = Número de gérmenes/cm^2 x 4 x 10
(2) mg/100 g pescado

Irradiación de arenques ahumados *Clupea harengus*

Cincuenta paquetes de 200 g (7 oz) de arenques ahumados salados y otros 50 paquetes del mismo peso de arenques sin sal, todos envasados en plástico "rilsan" al vacío se irradiaron a las siguientes dosis:

16 paquetes con	100.000 rad
16 paquetes con	200.000 rad
16 paquetes con	350.000 rad
16 paquetes con	600.000 rad
16 paquetes con	2.500.000 rad
20 paquetes no se irradiaron (testigo)	

Los resultados se expresan en los Cuadros 5 y 6 y figs 9 y 10.

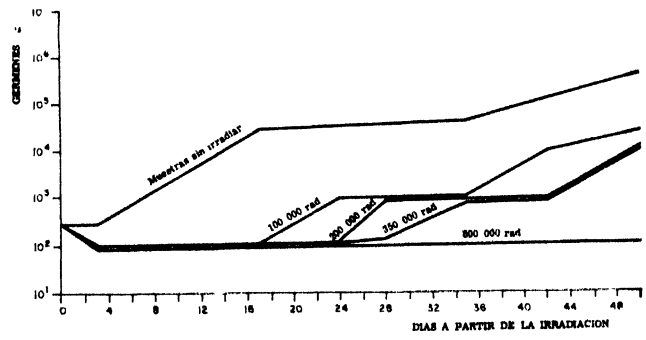


Fig 9. Desarrollo de la microflora en arenques ahumados salados. Temperatura de conservación 0°/+4°C

CUADRO 6. IRRADIACIÓN DE ARENQUES AHUMADOS SIN SAL (*Clupea harengus*); RESULTADOS MICROBIOLÓGICOS Y FÍSICO-QUÍMICOS
(Conservación a 0°/+4°C)

N°	Fecha	Dosis rad	SH_2	Indol	E.Coli I	Clostridium	Salmonella	Micrococcus	Coliformes (1)	Flora total (1)	pH	N BVT (2)	Car. org. *
1	5° día	Testigo	1	0	0	0	Estéril	<100	10^3	2×10^4	6,67	28,54	N
2	"	100.000	0	0	0	0	"	<100	10^2	2×10^3	6,50	11,35	N
3	"	200.000	0	0	0	0	"	<100	10^2	10^3	6,35	10,55	N
4	"	350.000	0	0	0	0	"	<100	<10^2	10^2	5,60	10,70	N
5	"	600.000	0	0	0	0	"	<100	<10^2	10^2	5,50	8,58	N
6	"	2.500.000	0	0	0	0	"	<100	<10^2	10^2	5,45	7,60	N
7	12°día	Testigo	1	0	0	0	Estéril	<100	2×10^3	5×10^4	6,58	31,06	N
8	"	100.000	0	0	0	0	"	<100	10^2	4×10^3	6,38	15,20	N
9	"	200.000	0	0	0	0	"	<100	10^2	10^3	6,32	12,55	N
10	"	350.000	0	0	0	0	"	<100	<10^2	10^2	6,05	10,80	N
11	19° día	Testigo	2	1	0	0	Estéril	<100	6×10^3	5×10^5	6,78	33,15	R
12	"	100.000	1	0	0	0	"	<100	10^3	3×10^4	6,70	20,26	N
13	"	200.000	0	0	0	0	"	<100	10^2	7×10^3	6,35	15,40	N
14	"	350.000	0	0	0	0	"	<100	<10^2	10^3	6,40	12,65	N
15	"	600.000	0	0	0	0	"	<100	<10^2	10^2	5,67	7,78	N
16	26°día	Testigo	3	2	0	0	Colonias verdes	<100	10^4	6×10^6	7,10	70,24	I
17	"	100.000	2	1	0	0	"	<100	5×10^3	4×10^5	6,90	45,70	R
18	"	200.000	1	0	0	0	"	<100	10^3	10^5	6,58	28,30	N
19	"	350.000	0	0	0	0	"	<100	<10^2	10^4	6,40	22,65	N
20	"	2.500.000	0	0	0	0	"	<100	<10^2	10^2	5,30	7,55	N
21	33°día	Testigo	-	-	-	-	-	-	-	-	-	-	-
22	"	100.000	3	2	0	0	Colonias verdes	<100	3×10^4	2×10^6	6,90	68,80	I
23	"	200.000	1	1	0	0	Estéril	<100	2×10^3	4×10^5	6,70	48,70	R
24	"	350.000	0	0	0	0	"	<100	10^3	10^4	6,25	32,20	N
25	"	600.000	0	0	0	0	"	<100	<10^2	10^2	5,54	16,36	N
26	40°día	Testigo	-	-	-	-	-	-	-	-	-	-	-
27	"	100.000	-	-	-	-	-	-	-	-	-	-	-
28	"	200.000	2	1	0	0	Estéril	<100	10^4	10^6	7,10	80,30	I
29	"	350.000	1	1	0	0	"	<100	10^3	10^4	6,28	27,25	N
30	"	-	-	-	-	-	-	-	-	-	-	-	-
31	47°día	Testigo	-	-	-	-	-	-	-	-	-	-	-
32	"	100.000	-	-	-	-	-	-	-	-	-	-	-
33	"	200.000	-	-	-	-	-	-	-	-	-	-	-
34	"	350.000	1	0	0	0	Estéril	<100	10^3	2×10^4	6,30	27,30	N
35	"	2.500.000	0	0	0	0	"	<100	<10^2	<10^2	5,45	8,46	N
36	50°día	Testigo	-	-	-	-	-	-	-	-	-	-	-
37	"	100.000	-	-	-	-	-	-	-	-	-	-	-
38	"	200.000	-	-	-	-	-	-	-	-	-	-	-
39	"	350.000	0	0	0	0	Estéril	<100	10^3	3×10^4	6,40	29,20	N
40	"	600.000	0	0	0	0	"	<100	<10^2	10^2	5,35	8,30	N

* N = Normal; R = Regular; I = Inaceptable
(1) Número de gérmenes/g = Número de gérmenes/cm^2 x 4 x 10
(2) mg/100 g pescado

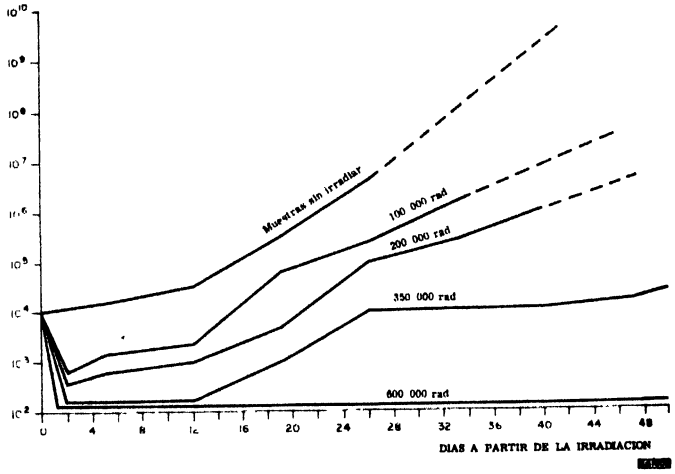


Fig 10. Evolución de la microflora en arenques ahumados sin sal. Temperatura de conservación 0°/+4°C

La irradiación en este tipo de pescado ahumado tanto si es salado como sin sal, se ha mostrado extraordinariamente eficax. Incluso a bajas dosis los gérmenes quedan casi por completo eliminados. La acción coadyuvante de la sal como microbicida, al producir deshidratación, contribuye a aumentar el período de conservación, en buen estado, de las muestras irradiadas con dosis de radurización, tal como se refleja en el Cuadro 5 y en la gráfica que lo representa (fig 9).

DISCUSION DE RESULTADOS

Aunque en cada experiencia se han interpretado los resultados, consideramos conveniente hacer una breve discusión comparativa de los resultados obtenidos en las diferentes especies de pescado.

En el primer grupo de pruebas se comprobó que los resultados de las muestras irradiadas con 0,275 Mrad, fueron suficientemente ventajosos para prolongar la vida comercial del pescado lo necesario para suplir las deficiencias de las actuales condiciones comerciales. En la segunda serie de exámenes, la dosis de 0,250 Mrad se mostró también eficaz para los mismos fines, siendo preferible mantenerlo a bajas temperaturas alrededor de 0° a 4°C (32° a 39°F). Por último, en la tercera experiencia se confirmaron los anteriores resultados, probándose que con las dosis de 0,200 Mrad se prolonga en tres veces el tiempo de almacenamiento con respecto a las muestras testigo.

En relación con los arenques ahumados se apreció una clara diferencia entre la conservación de los paquetes salados y sin sal. Irradiados a las dosis de 0,100 y 0,200 Mrad, la prolongación de la vida comercial resultó ser en los primeros del 25 al 30 por ciento mayor que en los segundos.

Es necesario acentuar que el pescado fresco se irradió en envases de forma comercial, le cual no proporciona una garantía absoluta para evitar recontaminaciones. Es indudable que si los resultados en las tres experiencias han sido, en general, favorables, podrían ser mejorados a medida que se perfeccionen los sistemas de envases, consiguiendo unas condiciones análogas a los paquetes de arenques ahumados.

Desde el punto de vista de la seguridad microbiológica, en ninguna de las tres series de pruebas del pescado fresco, ni en el pescado ahumado, se han encontrado gérmenes patógenos, habiéndose investigado: *Clostridium* sulfito reductores tipo Velchii *perfringens*, *Micrococcus* catalasa positivos, *Bacillus*, y, *Salmonella* y otras enterobacteriáceas patógenas. El riesgo de la existencia de *Clostridium botulínico*, tipo E y el posible desarrollo de su toxina en la microflora residual, de acuerdo con muchos autores, no consideramos constituya un peligro real en los mares de zonas templadas y cálidas. El pescado fresco, por otra parte, no puede desarrollar la toxina botulínica en un tiempo menor de 15 días en que se calcula debe ser vendido y consumido ni tampoco dicha toxina resiste las temperaturas de ebullición a que es sometido siempre antes de su consumo.

Las especies objeto de las experiencias son las más frecuentemente utilizadas para la preparación de filetes de pescado. Esta forma de presentación comercial tiende a extenderse en todos los países y cada vez en mayor número de especies, residiendo en este hecho el interés de conseguir una adecuada conservación todavía no lograda con los métodos clásicos. En la irradiación, como en los demás procedimientos de conservación, es muy importante partir de un producto lo más fresco y exento de contaminación posible. El estudio de las condiciones higiénicas de los locales y útiles de trabajo, mediante el análisis sistemático de muestras es un requisito indispensable para valorar las fuentes de contaminación de acuerdo con la carga microbiana, que en definitiva determinan las dosis más recomendables de irradiación.

Los análisis de partida de los filetes de pescado de las tres experiencias, han mostrado desde el punto de vista de la calidad bacteriológica y físico-química, que son sanos y aptos para el consumo. Aun partiendo de una buena calidad inicial, el tejido muscular del pescado está expuesto en todo momento al riesgo de contaminaciones y su vida comercial es sumamente corta. Estas razones fundamentales de orden sanitario y económico, aconsejan el tratamiento por irradiación. Los filetes de pescado, debidamente envasados e irradiados, pueden llegar a ser uno de los alimentos de mayor garantía higiénica y aceptación por el público consumidor.

CONCLUSIONES

De todo lo expuesto pueden deducirse las siguientes conclusiones:

(1) Los filetes de pescado fresco, irradiados con envases comerciales y conservados a temperatura de 0° a 4°C (32° a 39°F) mejoran la calidad higiénica y prolongan su vida comercial durante los siguientes períodos de tiempo según dosis:

Con 0,350 Mrad	18–21 días
Con 0,250 Mrad	15–18 días
Con 0,200 Mrad	10–12 días
Con 0,100 Mrad	7–8 días

(2) Las muestras de filetes de pescado, en las mismas condiciones y dosis de irradiación, pero conservadas a temperatura de 6° a 8°C (43° a 46°F) disminuyen los anteriores períodos de conservación del 20 al 25 por ciento.

(3) Los arenques ahumados salados con dosis de 0,200 Mrad, prolongan su buen estado de conservación 60 días como mímino.

(4) Los arenques ahumados con escasa cantidad de sal, prolongan la buena calidad higiénico-comercial de 45 a 60 días, al ser irradiados con dosis de 0,200 Mrad.

(5) En ninguna de las pruebas se detectaron cambios de olor, sabor ni de otros caracteres organolépticos.

Agradecimiento

Estos trabajos han podido ser realizados gracias a la generosa ayuda material y moral del Profesor Pierre Vidal, Presidente-Director General de la "Société Conservatome" y de sus colaboradores: M. Gouget y M. Haury, Ingeniero-Jefe y Técnico, respectivamente, de la Unidad de Irradiación I.R.M.A. 400/1.

Asimismo han prestado una eficaz e inestimable colaboración: el Dr. Rouve, Veterinario-Jefe del Laboratorio de Bacteriología de los Servicios Veterinarios de Vaugirard (París); el Dr. Cohen, Jefe del Grupo Farmacéutico del Departamento de Radioelementos del C.E.N. de Saclay y de sus colaboradores: Dr. Merlin, Mlle Costeroux y M. Valiant; Mlle Fournaud, M. Mocquot y M. Hermier, del Laboratorio de Microbiología del C.N.R.Z. de Jouy en Josas (Francia).

Bibliografia

ANON. 1964 Radiation preservation of food. Proceedings of an international conference, Boston, Massachusetts.

BUTTIAUX, R 1966 *Techniques Bacteriologiques*, Editorial Medical Flamarion, Paris.

COMISIÓN INTERMINISTERIAL ESPAÑOLA DE CONSERVACION DE ALIMENTOS POR IRRADIACION 1966 Proyecto sobre conservación de alimentos por irradiación. Informe técnico y bases para una legislación. Documento CI–66/4/3.

FAO/IAEA 1966 International symposium on food irradiation, Karlsruhe.

HANNAN, R S 1966 *Research on the Science and Technology of Food Preservation by Ionizing Radiation*, Chemical Publishing Co. Inc., New York.

RHODES, D N 1963 La pasteurisation du poisson par les radiations ionisantes. Agence européene pour l'energy nucleaire.

SOUDAN, FRANCE 1965 *La Conservation par le Froid des Poissons, Crustacés et Mollusques*, J. B. Ballière et fils, Paris, 514 pp.

VIDAL, P 1965 La radioexposition des produits de la mer. Société Conservatome.

Effect of Irradiation on the Keeping Quality of Packaged Cod Flesh

by J. van Mameren, K. J. A. van Spreekens, H. Houwing and D. A. A. Mossel

Effect of irradiation on the keeping quality of packaged cod flesh

The paper describes experiments in irradiation of ground fillets from fresh cod (*Gadus morhua*) packed in cellophane or vacuum-packed in Rilsan. Radiation doses of 0.15 to 0.25 Mrad were used without producing off-flavours or off-colours. When stored at 2°C (36°F) the irradiated samples vacuum-packed in Rilsan kept much longer (26 vs. 15 days) than those packed in cellophane. Total Volatile Bases (TVB) and aerobic plate counts were good spoilage indicators for both irradiated and non-irradiated samples packed in cellophane (not vacuum-packed) while Total Volatile Acids (TVA) appeared to have little value. For the non-irradiated vacuum-packed samples TVA, TVB and aerobic plate counts all appeared to be good indices. For the irradiated vacuum-packed samples only aerobic plate counts, and to a lesser extent TVA, seemed to be useful.

Les effets de l'irradiation sur la conservabilité de la chair de morue empaquetée

La communication décrit des expériences portant sur l'irradiation de filets broyés de morue fraîche (*Gadus morhua*) emballés dans de la cellophane ou empaquetés sous vide dans du Rilsan. Des doses de 0,15 à 0,25 Mrad ont été utilisées sans provoquer de dénaturation de la saveur ou de la couleur. Conservés à 2°C (36°F) les échantillons irradiés et emballés sous vide dans du Rilsan se conservaient beaucoup plus longtemps que ceux emballés sous cellophane (26 jours au lieu de 15 jours). La détermination des bases volatiles totales (BVT) et le dénombrement des bactéries aérobies constituent de bons indices de détérioration pour les échantillons, tant irradiés que non irradiés, emballés sous cellophane (mais non sous vide), tandis que la détermination des acides volatiles totaux (AVT) paraît présenter peu d'intérêt. En ce qui concerne les échantillons emballés sous vide et non irradiés, les AVT, les BVT et les dénombrements des bactéries aérobies paraissent constituer de bons indices. Pour ce qui est des échantillons emballés sous vide et irradiés, seules les numérations de bactéries aérobies et, à moindre degré, les AVT, semblent présenter un certain intérêt.

El efecto de la irradiación en la calidad de conservación de la carne de bacalao envasado

En el documento se describen los experimentos de irradiación llevados a cabo con filetes de bacalao fresco (*Gadus morhua*) envasado en celofán o al vacío, en Rilsan. Se emplearon dosis de irradiación de 0,15 a 0,25 Mrad sin pérdidas de sabor o de color. Cuando se almacenaron a 2°C (36°F) las muestras irradiadas envasadas al vacío en Rilsan se conservaron mucho más tiempo (26 en vez de 15 días) que las envasadas en celofán. Las bases volátiles totales (BVT) y los recuentos de aerobias en placas fueron buenos indicadores de las deterioraciones de las muestras irradiadas y no irradiadas envasadas en celofán (no envasadas al vacío), mientras que los ácidos volátiles totales (AVT) parecieron tener poca importancia. Con respecto a las muestras no irradiadas envasadas al vacío, parecieron ser buenos índices los AVT, las BVT así como los recuentos de aerobias en placas. Para las muestras irradiadas envasadas al vacío sólo parecieron ser útiles los recuentos de aerobias en placas y en menor medida los AVT.

MANY investigators have shown that irradiation of fresh fish at a dose of about 0.2 Mrad may prolong the keeping quality under refrigerated storage conditions without undue effects on acceptability (Connors and Steinberg, 1966; Corlett *et al.*, 1965, Emerson *et al.*, 1966; Hashish *et al.*, 1966; Kazanas *et al.*, 1966; Licciardello *et al.*, 1967; MacLean and Walander, 1960; Masurovsky *et al.*, 1963; Miyauchi, 1960; Pelroy and Eklund, 1966; Sinskey, Pablo and Silverman, 1967; Spinelli *et al.*, 1965; Tinker, Ronsivalli and Slavin, 1966). Some preliminary irradiation experiments carried out with packaged cod fillets of the type sold at supermarkets have shown that the shelf life of such fillets depends not only on the irradiation dose given, the mode of packaging and the subsequent storage temperatures, but also on the initial quality of the fish. In these tests it also became obvious that there was not always a correlation between the organoleptic quality and the usual tests for microbial metabolites such as total volatile acids.

In the experiments described in this paper, the influence of irradiation and packaging on the chemical and bacteriological changes of cod (*Gadus morhua*) during storage at 2°C (36°F) were compared.

EXPERIMENTAL

Material

In order to eliminate, as far as possible, the influence of heterogeneity of bacterial contamination, ground fillets prepared from very fresh cod were used in this experiment. The experimental samples were packed either in cellophane or under vacuum in Rilsan.

Irradiation

Radiation treatment was carried out at Euratom/ITAL-Association, Wageningen, The Netherlands, with a 1.7 MeV Van de Graaff accelerator. Doses varying from 0.15 to 0.25 Mrad were used.

Initially the cod was in partly frozen condition. The dose of radiation was applied from two sides, in one passage through the beam. The transport to and from the irradiation plant was carried out under refrigerated conditions and took about 2 h.

Bacteriological examination

At the beginning and during storage at 2°C (36°F) irradiated and unirradiated samples were examined for total aerobic count. Peptone/beef extract/yeast extract

agar was used as the enumeration medium. The plates were incubated at 23°C (73°F) for five days.

The counts obtained were expressed as the logarithm of the numbers of bacteria per gram of ground fillet.

Biochemical examination

As a rule, both Total Volatile Bases (TVB) and Total Volatile Acids (TVA) were determined, using the classical methods, as modified at our institutes.

For the determination of TVB, weighed samples of fish extract, adjusted to about pH 12 were distilled into boric acid. For the determination of TVA, the same fish extract was brought to about pH 3 and distilled with steam.

TVB is expressed in mg nitrogen per 100 g of fish (mgN/100 g), whereas the amounts of TVA are expressed in ml 0.01 N sodium hydroxide required per 100 g of fish (ml NaOH/100 g).

RESULTS AND DISCUSSION

The chemical and microbiological changes occurring in the irradiated and unirradiated samples during storage at 2°C (36°F) and the times at which they were definitely spoiled, are shown in table 1. From this data, the storage life of the samples has been assessed in table 2. It appears that the combination of vacuum packing in Rilsan and irradiation results in an extremely long storage life at 2°C (36°F).

It is obvious that in the case of the non-vacuum packed samples, TVB and the aerobic plate count at 23°C (73°F) are good spoilage indicators, for both non-irradiated, and irradiated samples, whereas TVA seems to be of no particular use.

In the case of the vacuum packed non-irradiated samples all analytical criteria used, TVA, TVB and the aerobic plate count were good spoilage indicators. However, in the case of the vacuum packed irradiated samples only the total aerobic plate count and to a very much lesser extent TVA were of any use. This can be understood from detailed microbiological studies (Licciardello, Ronsivalli and Slavin, 1967; Pelroy and Eklund, 1966) showing that the microflora of vacuum-packaged irradiated fishery products consists mainly of glucidolytic organisms such as *Lactobacteriaceae*, whereas in the spoilage of ordinary packed products *Achromobacter* spp. predominate (Licciardello, Ronsivalli and Slavin, 1967; Shiflett, Lee and Sinnhuber, 1966).

In no instance was any radiation-induced off-flavour or colour observed. This is in full agreement with the evidence obtained by others in similar studies, using doses below 0.25 Mrad (e.g. Connors and Steinberg, 1966).

Clearly successful radurization poses the problem of survival and subsequent development of *Cl. botulinum* type E. In this connection we have compared various methods for the detection of such spores in radurized fishery products. So far, the following technique was found satisfactory. Samples are first of all enriched in sulphite iron polymyxin broth (Mossel, 1959) at 28°C (82°F). Positive, i.e. black, enrichment cultures are treated by alcoholization (Johnston, Harmon and Kautter, 1964), followed by plating on to brain heart infusion egg yolk agar. Suspect colonies thus obtained are tested for motility, nitrate reduction, indole formation and I.P. toxicity of their cultures for mice.

TABLE 1. CHEMICAL AND MICROBIOLOGICAL CHANGES OF IRRADIATED AND UNIRRADIATED COD MATERIAL DURING STORAGE AT 2°C

Days	*Packed in cellophane*						*Vacuum packed in Rilsan*					
	Unirradiated			*Irradiated*			*Unirradiated*			*Irradiated*		
	*TVB**	*TVA†*	*Log. plate count*	*TVB**	*TVA†*	*Log. plate count*	*TVB**	*TVA†*	*Log. plate count*	*TVB**	*TVA†*	*Log. plate count*
0	‡	‡	6.1	‡	‡	3.6	‡	‡	6.3	‡	‡	3.6
1	13	5	‡	14	7	‡	‡	‡	‡	‡	‡	‡
4	13	6	7.2	14	10	3.6	‡	‡	‡	‡	‡	‡
6	18	2	8.3	16	7	4.2	‡	‡	‡	‡	‡	‡
8	40	4	9.0‖	15	7	5.3	20	10	8.0§	16	5	4.3
12				18	10	7.4	74	132	8.9‖	‡	‡	‡
15				25	5	8.3				18	6	5.8
18				48	6	8.9‖				18	6	5.8
20				84	7	8.9				‡	‡	‡
22				90	18	8.8				‡	‡	‡
26				80	15	‡				19	16	6.5§
29										18	6	6.0§
34										22	16	7.2§

* (mgN/100 g)
† (ml NaOH/100g)
‡ Not determined
§ Fishy odour
‖ Spoiled

TABLE 2. STORAGE LIFE OF THE COD MATERIAL AT 2°C, IN DAYS

	Packed in cellophane	*Vacuum packed in Rilsan*
Irradiated	15	26
Unirradiated	6	8

References

CONNORS, T J and STEINBERG, M A 1966 Preservation of fresh unfrozen fishery products by low-level radiation. IV. Organoleptic studies on radiation pasteurized skinless haddock fillets. *Fd Technol., Champaign*, **20**, 1357–1359.

CORLETT, D A, JR, LEE, J S and SINNHUBER, R O 1965 Application of replica plating and computer analyses for rapid identification of bacteria in some foods. II. Analysis of microbial flora in irradiated dover sole (*Microstomus pacificus*). *Appl. Microbiol.*, **13**, 818–822.

EMERSON, J A, KAZANAS, N, SEAGRAN, H L, GREIG, R A and
1966 KEMPE, L L Irradiation preservation of fresh-water fish. I. Extension of refrigerated storage life of fresh yellow perch fillets. *Fd Technol., Champaign*, **20**(2), 206–208.

HASHISH, S, HUSSEIN, M F, ABDEL-BAKI, M M, ROUSHDY, H M
1966 and HASSAN, Y M Preservation of the sardine *Sardinella melanura* by low-dose gamma radiation. *J. Fish. Res. Bd Can.*, **23**, 601–606.

JOHNSTON, R, HARMON, F and KAUTTER, D Methods to
1964 facilitate the isolation of *Clostridium botulinum* type E. *J. Bact.*, **88**, 1521–1522.

KAZANAS, N, EMERSON, J A, SEAGRAN, H L and KEMPE, L L
1966 Effect of gamma irradiation on the microflora of fresh-water fish. I. Microbial load, lag period and rate of growth on yellow perch (*Perca flavescens*) fillets. *Appl. Microbiol.* **14**, 261–266.

LICCIARDELLO, J J, RONSIVALLI, L J and SLAVIN, J W Effect
1967 of oxygen tension on the spoilage microflora of irradiated and non-irradiated haddock (*Melagogrammus aeglefinus*) fillets. *J. appl. Bact.*, **30**, 239–245.

MACLEAN, D P and WELANDER, C The preservation of fish
1960 with ionizing radiation. Bacterial studies. *Fd Technol., Champaign*, **14**(5), 1–254.

MASUROVSKY, E B, GOLDBLITH, S A and NICKERSON, J T R
1963 Effect of substerilization doses of ^{60}Co gamma rays on the cold storage life extension of shucked soft shelled clams and haddock fillets. *Appl. Microbiol.*, **11**, 220–228.

MIYAUCHI, D T Irradiation preservation of Pacific northwest
1960 fish. I. Cod fillets. *Fd Technol., Champaign*, **14**(8), 379–382.

MOSSEL, D A A Enumeration of sulphite reducing Clostridia
1959 occurring in foods. *J. Sci. Fd Agric.*, **10**, 622–669.

PELROY, G A and EKLUND, M W Changes in the microflora of
1966 vacuum packaged irradiated petrale sole (*Eopsetta jordani*). Fillets stored at 0·5°C. *Appl. Microbiol.*, **14**, 921–927.

SHIFLETT, M A, LEE, J S and SINNHUBER, R O Microbial flora
1966 of irradiated Dungeness crab meat and pacific oysters. *Ibid.*, **14**, 411–415.

SINSKEY, T J, PABLO, I S and SILVERMAN, G J Effect of
1967 packaging on the major microbial flora of irradiated haddock. *Nature, Lond.*, **213**, 425–426.

SPINELLI, J, EKLUND, M, STOLL, N and MIYAUCHI, D
1965 Irradiation preservation of Pacific coast fish and shellfish. III. Storage life of petrale sole fillets. *Fd Technol., Champaign*, **19**, 1016–1020.

TINKER, R L, RONSIVALLI, L J and SLAVIN, J W Suitability of
1966 flexible plastics as packaging materials for radiopasteurized seafoods. *Ibid.*, **20**, 1362–1364.

Preliminary Experiments on the use of Irradiation to Destroy Enteropathogenic Bacteria on Freshwater Fish

by D. A. A. Mossel and K. J. A. van Spreekens

Preliminary experiments on the use of irradiation to destroy enteropathogenic bacteria on freshwater fish

Preliminary experiments to test the practicability of radicidation for the destruction of enteropathogenic bacteria on freshwater fish are described. The organisms tested were *Salmonella typhimurium* isolated from pork, and strains of *Klebsiella* and *Flavobacter* isolated from freshwater fish. Inoculations were made into previously irradiated and ground freshwater fish at levels of a 10^{10}/g. Radiation doses of from 0.1 to 0.6 Mrad were used. The survival curves were virtually linear and from these the following Decimal Reduction Values (D) were calculated:

Salmonella typhimurium	0.050 Mrad
Klebsiella species	0.035 Mrad
Flavobacter species	0.060 Mrad

Expériences préliminaires sur l'emploi de l'irradiation pour détruire les bacteries entéropathogènes dans les poissons d'eau douce

La communication décrit les expériences préliminaires menées en vue d'éprouver les possibilités d'emploi des radiations pour détruire les bactéries entéropathogènes dans les poissons d'eau douce. Les essais ont porté sur les organismes suivants: *Salmonella typhimurium*, isolée à partir du porc et des souches de *Klebsiella* et *Flavobacter* isolées des poissons d'eau douce. Des innoculations ont été pratiquées à raison de 10^{10}/g dans des poissons d'eau douce, irradiés et broyés au préalable. Les doses d'irradiation ont varié de 0,1 à 0,6 Mrad. A partir des courbes de survie, pratiquement linéaires, on a calculé les valeurs de réductions décimale suivantes:

Salmonella typhimurium	0,050 Mrad
Klebsiella espèces	0,035 Mrad
Flavobacter espèces	0,060 Mrad

Experimentos preliminares sobre el empleo de las irradiaciones para destruir las bacterias enteropatógenas de los peces de agua dulce

Se describen los experimentos preliminares realizados para ensayar la posibilidad de emplear radiaciones con objeto de destruir las bacterias enteropatógenas de los peces de agua dulce. Los organismos probados fueron *Salmonella typhimurium*, aislados del cerdo, y las cepas de *Klebsiella* y *Flavobacter*, aisladas de peces de agua dulce. Se hicieron inoculaciones en peces, previamente irradiados, de agua dulce y de fondo a niveles de 10^{10}/g. Se emplearon dosis de radiación desde 0,1 a 0,6 Mrad. Las curvas de supervivencia fueron virtualmente lineables y a partir de ellas se calcularon los siguientes valores de reducción decimal (D):

Salmonella typhimurium	0,050 Mrad
Klebsiella especies	0,035 Mrad
Flavobacter especies	0,060 Mrad

IT has been shown that freshwater systems are often heavily contaminated with all sorts of Enterobacteriaceae and it is obvious that fish caught in such waters will, in many cases, also be contaminated (Floyd and Jones, 1954; Hemmes, 1964; Jadin, Resseler and van Looy, 1957; Kapsenberg, 1938; Olitzky *et al.*, 1956; Ruys, 1948). Hence, methods for the elimination of Enterobacteriaceae and in particular of Salmonellae from freshwater fish are of interest. Therefore, preliminary experiments have been carried out on the radicidation of freshwater fish.

EXPERIMENTAL

Inoculation

In exploratory tests it became clear that the natural contamination of Dutch freshwater fish with Enterobacteriaceae was at a rather low level. In order to arrive at a reliable estimation of the dose required for effective radicidation it was, therefore, necessary to inoculate the freshwater fish artificially.

For this purpose the indigenous Enterobacteriaceae of the fish were destroyed by irradiation in the frozen state with 0.5 Mrad γ-rays. For the subsequent inoculation of this irradiated freshwater fish, three strains were used. These were *Salmonella typhimurium* isolated from pork and two strains isolated from freshwater fish, namely a *Klebsiella* species and an oxidative *Flavobacter* that grew well in the media commonly used for the detection of Enterobacteriaceae.

In order to guarantee a rather homogeneous inoculation, the fish was first ground and then very intensively mixed with a bacterial paste, obtained by centrifugation of broth cultures. In this way initial counts of the order 10^{10}/g were attained.

Irradiation

The inoculated material was packed in glass tubes which were 18 mm in diameter and were provided with rubber caps. Irradiation was carried out at the Centre for Nuclear Research, Mol, Belgium, using a Gamma cell having a flux of 0.70 Mrad/h. The irradiated material was kept at a temperature of about $-10°C$ ($+14°F$). Doses varying from 0.1 to 0.6 Mrad were used.

Bacteriological examination

Viable numbers of Enterobacteriaceae of the order of 20 g or more were determined by making poured plate counts, using violet red bile glucose agar (Mossel, Mengerink and Scholtz, 1962). Numbers of bacteria below 20 g were assessed by making Most Probable

Number (MPN) dilution counts. Buffered brilliant green bile glucose broth was used as the primary enrichment medium (Mossel, Visser and Cornelissen, 1963). After incubation for up to 48 h at 37°C (98.6°F), tubes were streaked on to plates of violet red bile glucose agar, which were then incubated for 24 h. Colonies obtained in this way were tested for the characters of the bacteria used as the inoculum-cytochrome oxidase reaction, mode of attack on glucose and nitrate reduction.

RESULTS AND DISCUSSION

The survival curves obtained were virtually linear. From these the following Decimal Reduction Values (D) for the three strains used could be calculated:

Salmonella typhimurium	0.050 Mrad
Klebsiella species	0.035 Mrad
Flavobacter species	0.060 Mrad

Ley, Freeman and Hobbs (1963) found Decimal Reduction Values for *Salmonella* species in frozen meat and frozen eggs varying from 0.043 to 0.130 Mrad, while Comer *et al.* (1963) estimated these values to be between 0.05 and 0.08 Mrad. Our values are in rather good agreement with these published results.

Hence, if *Salmonella* radicidation of frozen freshwater fish is considered effective and, in addition, is found to produce organoleptically acceptable products the mode of processing suggested by Ley (1963) for frozen meats could be followed and the cost estimates of this author would also apply.

References

CANN, D C, WILSON, B B, SHEWAN, J M and HOBBS, G 1966 Incidence of *Clostridium botulinum* type E in fish products in the United Kingdom. *Nature, Lond.*, **211**, 205–206.

COMER, A G, ANDERSON, G W and GARRARD, E H 1963 Gamma irradiation of *Salmonella* species in frozen whole egg *Can. J. Microbiol.*, **9**, 321–327.

DANIELS, J J H M 1962 De eosinofiele flegmone van het maag-darmkanaal veroorzaakt door de haringworm. *Ned. Tydschr. Geneesk.*, **106**, 131–132.

FLOYD, T M and JONES, G B 1954 Isolation of *Shighella* and *Salmonella* organisms from Nile fish. *Am. J. trop. Med. Hyg.*, **3**, 475–480.

HEMMES, G D 1946 Paratyphus overgebracht door gerookte paling. *Ned. Tydschr. Geneesk.*, **90**, 80–81.

JADIN, J, RESSELER, J and LOOY, G VAN 1957 Présence de *Shighella* et de *Salmonella* chez les poissons et dans les eaux des grands lacs du Congo belge et du Ruanda-Urundi. *Bull. Acad. r. Méd. Belg.*, **22**, 85–96.

KAPSENBERG, G 1938 Salmonellose bij den mensch veroorzaakt door S. enteritidis var. essen, na het eten van visch (snoek). *Antonie van Leeuwenhoek*, **5**, 54–62.

KUIPERS, F C 1964 Pathogenese van de haringwormflegmone bij de mens. *Ibid.*, **108**, 304–305.

KUIPERS, F C, KAMPELMACHER, E H and STEENBERGEN, F 1963 Onderzoekingen over haringwormziekte bij konijnen. *Ibid.*, **107**, 990–995.

KUIPERS, F C, VAN THIEL, P H and ROSKAM, R TH 1960 Eosinofiele flegmone van de dunne darm, veroorzaakt door een niet aan het lechaam van de mens aangepaste worm. *Ibid.*, **104**, 422–427.

LEY, F J, FREEMAN, B M and HOBBS, B C 1963 The use of gamma radiation for the elimination of *Salmonella* from various foods. *J. Hyg., Camb.*, **61**, 515–529.

LEY, F J 1963 Technological aspects of food irradiation with particular reference to *Salmonellae* elimination. *Int. atom. Energy Ag. Tech. Rep.*, Ser. 22, p. 107.

MOSSEL, D A A, MENGERINK, W H J and SCHOLTS, H H 1962 A McConkey type agar medium for the selective growth and enumeration of all Enterobacteriaceae. *J. Bact.*, **84**, 381.

MOSSEL, D A, VISSER, M and CORNELISSEN, A M R 1963 The examination of foods for Enterobacteriaceae using a test of the type generally adopted for the detection of *Salmonellae*. *J. appl. Bact.*, **26**, 444–452.

OLITZKY, I, PERRI, A M, SCHIFFMAN, M A and WERRIN, M 1956 Smoked fish as a vehicle of salmonellosis. *Publ. Hlth Rep., Wash.*, **71**, 773–779.

ROSKAM, R TH 1966 *Anisakis larvae in North Sea herring*, International Council for the Exploration of the Sea, C.M. H13. (Mimeo.)

RODENBERG, W and WIELINGA, W J 1960 Eosinofiele flegmone van de dunne darm, veroorzaakt door een worm. *Ibid.*, **104**, 417–421.

RUYS, A C 1948 Bacteriological and epidemiological data on typhoid fever in Amsterdam. *Am. J. publ. Hlth*, **38**, 1219–1224.

Effect of Irradiation on *Anisakis* Larvae in Salted Herring

by J. van Mameren and H. Houwing

Effect of irradiation on *Anisakis* larvae in salted herring

The authors describe experiments to test the practicability of using irradiation to kill *Anisakis marina* larvae in lightly-salted herring (*Clupea harengus*). The lower salt concentration used since the Second World War for the preservation of gibbed herring is insufficient to kill the parasites which may be harmful to the consumer. The nemotodes were subjected to irradiation, either in water or saline suspension, or pressed between salted herring fillets or *in situ* in salted gibbed herring. The results were disappointing. In aqueous suspensions, a salt concentration of 6 per cent and a dose of 1.0 Mrad resulted in 100 per cent kill, but appreciable numbers survived (although many of these were inactive) at lower irradiation dosages and at lower salt concentrations. It was noted that for doses of either 0 or 0.3 Mrad the highest proportion of survivals occurred in 3 per cent salt solutions. In testing the effect of irradiation on parasites in the fish or placed between fillets the dosages were limited, because of flavour and colour changes, to 0.3 Mrad for salted ripened herring, and 0.6 Mrad for five-day-old lightly-salted herring. Substantial numbers of nemotodes survived these doses.

Effets de l'irradiation sur les larves d'*anisakis* dans le hareng salé

Les auteurs décrivent des expériences visant à déterminer la possibilité d'employer les radiations pour tuer les larves d'*Anisakis marina* dans le hareng légèrement salé (*Clupea harengus*). Depuis la deuxième guerre mondiale on utilise pour la conservation du hareng éviscéré (sans ouverture de l'abdomen) une concentration de sel moins forte qu'auparavant, qui se révèle insuffisante pour tuer les parasites qui risquent d'être nuisibles aux consommateurs. Les nématodes ont fait l'object d'irradiation, soit dans de l'eau ou dans une suspension saline, soit comprimées entre des filets de hareng salés ou *in situ* dans du hareng salé eviscéré. Les résultats suivants ont été obtenus: en suspension aqueuse, une concentration saline de 6 pour cent et une dose de 1,0 Mrad assurent une destruction totale des parasites, mais avec des doses d'irradiation plus faibles et des concentrations salines inférieures un nombre considérable de nématodes survit (nombre d'entre eux étant toutefois inactifs). On a observé qu'avec des doses de 0 ou de 0,3 Mrad, les plus fortes proportions de survie se produisent dans des solutions salines à 3 pour cent. Dans les essais visant à déterminer l'efficacité de l'irradiation sur les parasites dans le poisson ou placés entre les filets, il a fallu, en raison des modifications de saveur et de coloration, limiter les doses à 0,3 Mrad pour le hareng mûri au sel et à 0,6 Mrad pour le hareng de cinq jours légèrement salé. On a constaté qu'à ces doses un nombre considérable de nématodes survivait.

El efecto de la irradiación sobre las larvas *anisakis* del arenque salado

Los autores describen los experimentos realizados para probar la posibilidad de emplear las radiaciones con objeto de matar las larvas de *Anisakis marina* en el arenque ligeramente salado (*Clupea harengus*). La menor concentración de sal que se emplea desde la segunda guerra mundial para conservar el arenque sin branquias y parcialmente destripado es insuficiente para matar los parásitos que pueden dañar al consumidor. Los nematodos estuvieron sujetos a irradiación bien en agua o en suspensión salina, o bien comprimidos entre filetes de arenque salado, o *in situ* en arenque salado sin branquias y parcialmente destripado. Los resultados fueron desalentadores. En suspensiones acuosas una concentración de sal del 6 por ciento y una dosis de 1,0 Mrad lograron destruir larvas al 100 por ciento pero sobrevivieron cantidades apreciables (aunque muchas de ellas eran inactivas) con menores dosis de irradiación y menores concentraciones de sal. Se observó que con dosis de 0 o de 0,3 Mrad, la proporción más elevada de supervivencia se dio en soluciones de sal del 3 por ciento. Al ensayar el efecto de la irradiación sobre los parásitos de los peces, o en los parásitos situados entre los filetes, las dosis se limitaron a 0,3 Mrad respecto al arenque maduro y salado y a 0,6 Mrad para el arenque de cinco días ligeramente salado, debido a los cambios ocurridos en el sabor y color. Grandes cantidades de nematodos sobrevivieron a estas dosis.

ANISAKIS MARINA is a nematode occurring as a parasite in the intestines of sea mammals in the North Sea, such as dolphins, whales and seals.

Eggs excreted in the faeces of these mammals develop into white-coloured larvae, 15 to 25 mm in length and 1 mm thick. Plankton is thought to be a medium in which the larvae develop from the eggs. The larvae are swallowed by herrings (*Clupea harengus*) either directly or attached to the planktonic food. The larvae then penetrate into the belly of the herring and sometimes into the muscle tissue.

Since 1955 it is known that *Anisakis* larvae may present a risk to the consumer. Consumption of gibbed,* slightly salted herring sometimes results in the occurrence of phlegmons of the intestinal tract.

The concentration of larvae is greatest in the larger (i.e. older) herrings. The lower salt concentration, used for the preservation of gibbed herrings since the Second World War, is insufficiently high to kill the nematode larvae in the fish. Although saturated salt solution kills the nematode within 2 h they will survive for at least two days in a salt solution corresponding to lightly salted herring (i.e. 30 g NaCl/l). Furthermore the muscle tissue and body fat of fish seem to protect them and hence allow a much longer survival under practical conditions. The larvae survive even after 10 days in gastric acid at 37°C (98.6°F).

Freezing herring is an effective means for destroying the larvae, −20°C (−4°F) being a temperature low enough to kill them within 24 h.

While studying means to control the infection problem, attention has been given to the possibility of using radiation to kill nematode larvae in herring. The present report deals with this part of the study.

EXPERIMENTAL

Materials

The nematodes were isolated from infected, freshly-caught herrings.

For one series of tests groups of 20 larvae were packed in Rilsan bags, containing either distilled water or sodium chloride solutions of 3, 6 and 9 per cent. Some bags were filled with 60 nematodes to serve as controls.

* Gibbing is the practice of removing gills, heart, stomach, liver and gall of the herring by cutting with a sharp knife. Stomach appendices and part of the intestine, containing enzymes important for development of ripeness, are left.

For a practical test, samples of 20 larvae each were packed between herring fillets and vacuum sealed. A number of irradiation experiments were also carried out utilizing lightly salted, non-filleted herring. In this instance the numbers of nematodes in the test material and their vitality were unknown.

Irradiation

The herring and larvae in salt solution were irradiated with a Van de Graaf accelerator, equipped with a gold target. The maximum "Bremsstrahlung" energy was 1.5 MeV.

The herring samples were irradiated with 0.3 and 0.6 Mrad at an average dose rate of 0.003 Mrad/min. The nematodes in salt solutions were irradiated with doses varying from 0.3 to 1.0 Mrad at a dose rate of 0.006 Mrad/min. The temperature of all samples during irradiation was 5° to 10°C (41° to 50°F).

Vitality tests

The irradiated nematodes were first of all transferred to a 1.5 per cent NaCl solution. After 3 h they were removed for classification into three categories:

(1) actively alive;
(2) in coma, i.e. not actively moving but reacting to contact with a needle;
(3) dead.

This technique was necessary, since earlier experiments had shown that it was impossible to distinguish dead and living larvae by means of a staining reaction.

Taste testing

The effect of irradiation on the organoleptic quality of the product was evaluated by a panel of five experts of the Institute for Fishery Products TNO. This was done by comparing treated and untreated samples. Special attention was given to the occurrence of rancidity.

RESULTS AND CONCLUSIONS

The results of the *in vitro* irradiation experiments with nematodes are summarized in table 1.

It can be concluded from this table that a 100 per cent kill of nematodes is attained only with an irradiation dose of 1.0 Mrad and at a salt concentration of at least 6.0 per cent. At an irradiation dose of 0.3 Mrad and a salt concentration of 6 per cent or more a kill of 55 to 70 per cent was reached.

It is worthwhile to note that the larvae of *Anisakis marina* survived best in the 3 per cent salt solution.

Selection of the irradiation doses for larvae in salted herring was based primarily on the results of comparative organoleptic testing of treated and untreated products. Irradiation of salted ripened herring at 0.3 Mrad was found to cause slight changes in taste and colour; however, these were still not objectionable.

For five-day-old, lightly salted herring, the maximum permissible dose appeared to be 0.6 Mrad, although, here again, slight changes in taste and colour were detectable. The results of the irradiation experiments, in which 20 *Anisakis* larvae were packed between such herring fillets, are summarized in table 2.

Apparently irradiation at this level did not lead to a significant loss in viability.

The results of similar irradiation experiments with vacuum-packed, salted, gibbed herring have been recorded in tables 3 and 4.

TABLE 2. SURVIVAL OF ANISAKIS LARVAE PACKED BETWEEN HERRING FILLETS AND IRRADIATED WITH 0.6 MRAD

Product	*Larvae*		
	Dead (%)	*In coma* (%)	*Alive* (%)
Herring fillets, 5% salt, vacuum packed, 20 larvae inserted, not irradiated	4	4	92
Idem, irradiated 0.6 Mrad	9	9	82

TABLE 3. SURVIVAL OF ANISAKIS LARVAE IN VACUUM-PACKED SALTED RIPENED HERRING AFTER IRRADIATION WITH 0.3 MRAD

Product	*Larvae*		
	Dead (%)	*In coma* (%)	*Alive* (%)
Gibbed herring, 5% salt, vacuum packed, not irradiated	61	14	25
Idem, irradiated 0.3 Mrad	46	22	32

TABLE 4. SURVIVAL OF ANISAKIS LARVAE IN VACUUM-PACKED LIGHTLY SALTED HERRING AFTER IRRADIATION WITH 0.6 MRAD

Product	*Larvae*		
	Dead (%)	*In coma* (%)	*Alive* (%)
Gibbed herring, 5% salt, vacuum packed, not irradiated	51	5	44
Idem, irradiated 0.6 Mrad	47	9	44

TABLE 1. SURVIVAL OF ANISAKIS LARVAE IN DIFFERENT NaCl SOLUTIONS AFTER IRRADIATION WITH 0 0.3 0.6 AND 1.0 MRAD

Irradiation dose (*Mrad*)	0 *per cent NaCl*			3 *per cent NaCl*			6 *per cent NaCl*			9 *per cent NaCl*		
	Dead (%)	*In coma* (%)	*Alive* (%)	*Dead* (%)	*In coma* (%)	*Alive* (%)	*Dead* (%)	*In coma* (%)	*Alive* (%)	*Dead* (%)	*In coma* (%)	*Alive* (%)
0	72	28	0	4	85	11	25	68	7	87	13	0
0.3	20	80	0	5	95	0	55	45	0	70	30	0
0.6	50	50	0	55	45	0	45	55	0	55	45	0
1.0	75	25		85	15		100	0		100	0	

As could be expected, in this instance irradiation at a dose of 0.6 Mrad had no effect.

These results do not at all agree with those obtained by irradiation *in vitro*. This discrepancy could perhaps be explained by the protection against irradiation given by the herring tissue.

These rather disappointing results with respect to larval kill under practical conditions prompted an investigation as to whether sublethally damaged larvae might be non-infectious and therefore not of pathological interest. Some preliminary experiments along these lines, using sensitized rabbits as test animals have been carried out.

It has been proved that rabbits react in the same way as men, i.e. that the rabbits also produce antagonic products, the strength of which can be determined in the blood, and also that the phlegmons are occurring.

A group of 13 rabbits was given a dose of 40 *non*-irradiated larvae. Seven days later a second dose of 40 non-irradiated larvae was given. Ten days after the first infection a *post-mortem* examination was carried out. With 10 rabbits a very clear ulcera (i.e. phlegmonic inflammation) of the stomach was observed in the fundic part.

In the other three cases only a primary infection was found.

Another group of rabbits was given a dose of 40 irradiated larvae in the same way. The irradiation dose was 0.6 Mrad γ-rays. None of the rabbits showed the inflammation. Not even a primary infection was found.

On further examination of the intestines of the rabbits, no resting or penetrating larvae were found.

Pathological anatomical results show that there is a difference in the effect of irradiated and non-irradiated larvae, but in neither case was any serological difference found between the groups.

Further research in this area must be done to determine why the blood can contain antagonic products in the case where the normal symptoms of the herringworm disease are not apparent.

If these experiments produce further encouraging results, another problem will arise concerning the development of *Clostridium botulinum* in the irradiated product during cold storage (Cann *et al.*, 1966).

References

THIEL, P H VAN and HOUTEN, H VAN 1966 De haringworm *Anisakis marina* als parasiet van de mens, buiten de wand van het maagdarmkanaal. *Ned. Tydschr. Geneesk.*, **110**, 1524–1527.

THIEL, P H VAN 1966 The final hosts of the herringworm *Anisakis marina*. *Trop. geogr. Med.*, **18**, 310–328.

Irradiation Inactivation of Food Infection Micro-Organisms in Seafoods

by A. W. Anderson

Irradiation inactivation of food infection micro-organisms in seafoods

Studies were conducted under controlled conditions in order to observe the resultant survival patterns of strains of pathogenic food contaminants in crab meat (*Cancer magister*), shrimp meat (*Pandalus jordani*), oyster meat (*Crassostrea gigas*), salmon (*Oncorhynchus*) and Hartsell's broth after exposure to ^{60}Co irradiation. The organisms used include the following *Salmonella*: *S. typhi*, *S. paratyphi* A, *S. paratyphi* B, *S. choleraesuis*, *S. enteritidis*, *S. pullorum*, *S. wichita*; the following *Shigella*: *Shigella dysenteriae*, *Shigella paradysenteriae* and *Shigella sonnei*; the following species from other genera: *Escherichia coli*, *Streptococcus faecalis*, *Proteous vulgaris*, *Neisseria catarrhalis* and *Mycobacterium smegmatis*. Each species was exposed to a series of irradiation levels from 0.05 to 1 Mrad in the above seafoods and growth medium. The food mediums used were prepared from commercially canned crab and from fresh raw shrimps, oysters and salmon. Each sample was test inoculated with approximately 1×10^6 micro-organisms per gram.

The results were plotted and the levels required for radurization (pasteurization) determined. There was considerable variation in the survival patterns depending upon the substrate and the micro-organisms.

A "tailing off" was observed in the survival patterns of *S. paratyphi* A, *S. pullorum*, *S. enteritidis*, *S. typhi*, *S. cholerasuis*, *Staphylococcus aureus* and *Streptococcus pyogenes* in all the seafoods, but absent or only slightly apparent in Hartsell's broth.

Apart from *Staphylococcus aureus* and *Streptococcus pyogenes*, *Salmonella typhosa*, *Salmonella paratyphi* B, *Salmonella wichita* and *Salmonella choleraesuis* were the most resistant of all the pathogens tested.

The "tailing off" phenomenon was very marked in some of the seafood products. By the use of enrichment techniques, the more resistant *Salmonella* could be recovered at 1 Mrad. The D values were determined in each case. The results indicate that predictable radurization doses based upon D values would be inaccurate if based on the inactivation curve or if determined on one substrate. Each product would have to be examined and dose levels determined.

Inactivation par irradiation des micro-organismes infectant les produits alimentaires marins

Des échantillons de crabe (*Cancer magister*), de crevettes (*Pandalus jordani*), d'huîtres (*Crassostrea gigas*), de saumon (*Oncorhynchus*) et un bouillon d'Hartsell ont été examinés dans des conditions contrôlées, après exposition à des radiations de ^{60}Co, en vue de déterminer le schéma de survie de souches d'éléments pathogènes des produits alimentaires.

Les organismes utilisés comprenaient les espèces suivantes de *Salmonellae*: *S. typhi*, *S. paratyphi* A, *S. paratyphi* B, *S. choleraesuis*, *S. enteritidis*, *S. pullorum*, *S. wichita*, les espèces suivantes de *Shigellae*: *Shigella dysenteriae*, *Shigella paradysenteriae* et *Shigella sonnei*, et certaines espèces des genres suivants: *Escherichia coli*, *Streptococcus faecalis*, *Proteus vulgaris*, *Neisseria catarrhalis* et *Mycobacterium smegmatis*. Chaque espèce a été exposée à une série d'irradiations dans les échantillons de produits marins et dans le milieu de culture, à des doses variant entre 0,05 Mrad et 1 Mrad. Les milieux alimentaires ont été créés à partir de crabe en boîte du commerce et d'échantillons crus frais de crevettes, d'huîtres et de saumon. Aux fins d'expérience, on a inoculé à chaque échantillon environ 1×10^6 micro-organismes. Les résultats ont été enregistrés et les niveaux requis pour la radio-pasteurisation ont été déterminés. Suivant le substrat et les micro-organismes considérés, les schémas de survie ont considérablement varié.

On a noté un aplatissement asymptotique de la courbe relative au schéma de survie de *S. paratyphi* A, de *S. pullorum*, *S. enteritidis*, *S. typhi*, *S. cholerasuis*, *Staphylococcus aureus* et chez *Streptococcus pyogenes* pour tous les produits marins, mais non, ou très peu, pour le bouillon d'Hartsell.

Exception faite de *Staphylococcus aureus* et *Streptococcus pyogenes*, les plus résistants des agents pathogènes étudiés étaient *Salmonella typhosa*, *Salmonella paratyphi* B, *Salmonella wichita* et *Salmonella choleraesuis*.

L'effet représenté par l'aplatissement de la courbe a été particulièrement marqué pour certains produits marins. Les *Salmonellae*, plus résistantes, pourraient être récupérées à 1 Mrad si l'on utilise des techniques d'enrichissement. La valeur D a été déterminée dans chaque cas. Il ressort des résultats que les doses prévues pour la radio-pasteurisation ne peuvent être connues avec précision si l'on tient compte de la seule courbe d'inactivation ou d'un seul substrat. Il conviendrait d'examiner chaque produit et de déterminer les doses.

Inactivación por irradiaciones de los microorganismos que infectan a los alimentos marinos

Se relizaron estudios en condiciones reguladas con objeto de observar las formas resultantes de supervivencia de razas de contaminantes patógenos de los alimentos existentes en la carne de cangrejo (*Cancer magister*), carne de camarón (*Pandalus jordani*), carne de ostra (*Crassostrea gigans*), salmón (*Oncorhyncus*), y en el caldo de cultivo de Hartsell después de exponerlos a irradiaciones de ^{60}Co. Los organismos utilizados incluían los *Salmonella* siguientes: *S. thyphi*, *S. paratyphi* A, *S. paratyphi* B, *S. choleraesuis*, *S. enteritidis*, *S. pullorum*, *S. wichita*; los *Shigella* siguientes: *Shigella dysenteriae*, *Shigella paradysenteriae* y *Shigella sonnei*; las especies siguientes de otros géneros: *Escherichia coli*, *Streptococcus faecalis*, *Proteous vulgaris*, *Neisseria catarrhalis* y *Mycobacterium smegmatis*. Cada especie se expuso a una serie de intensidades de irradiación de 0,05 Mrad a 1 Mrad, en los alimentos marinos anteriormente citados y en caldos de cultivo. Los alimentos utilizados como medio se prepararon con cangrejos comercialmente enlatados y con camarones, ostras y salmón frescos. A cada muestra se le inocularon aproximadamente 1×10^6 microorganismos por gramo.

Los resultados se representaron praticamente y se determinaron las intensidades necessarias para la "radurización" (pasteurización). La variación de los tipos de supervivencia fue considerable, dependiendo del substrato y de los microorganismos.

En las formas de supervivencia de *S. paratyphi* A, *S. pullorum*, *S. enteri idis*, *S. typhi*, *S. cholerasuis*, *Staphylococcus aureus* y *Streptococcus pyogenes* se observó una "disminución" en todos los alimentos marinos, pero tal "disminución" faltaba o era solo muy ligera en el caldo de Hartsell.

Con excepción de *Staphylococcus aureus* y *Streptococcus pyogenes*, *Salmonella typhosa*, *Salmonella paratyphi* B, *Salmonella wichita* y *Salmonella choleraesuis* fueron los más resistentes de todos los patógenos ensayados.

El fenómeno de "disminución" fue muy marcado en algunos alimentos marinos. Con el empleo de técnicas de enriquecimiento, las *Salmonella*, más resistentes, pudieron recuperarse a 1 Mrad. En cada uno de los casos se determinaron los valores D. Los resultados indican que las dosis de radurización pronosticadas, fundamentadas en valores D serían inexactas si se basaran en la curva de inactivación o si se determinaran en un solo substrato. En ese caso, tendría que examinarse cada producto y determinarse los niveles de las dosis.

AN important aspect of the future application of irradiation for the preservation of foods is that of insuring that food for humans and in certain cases, animals, be free of pathogens. Studies have shown that micro-organisms are more resistant when radiated in a complex medium such as nutrient broth than when irradiated in buffer or distilled water (Bridges and Horne, 1959). Thus, as the chemical complexity of the growth environment is increased, there is usually a concomitant increase in the protective effect of the medium. This

variation in the chemical nature of foods will make it necessary to test the irradiation resistance of each species, or even each strain of a species in each food product.

In this investigation we have compared the relative resistances and observed the survival patterns in different suspensions using non-sporeforming food intoxication and infection micro-organisms associated with seafoods. Previous experiments reported (Dyer, Anderson and Dutiyabodhi, 1966) were designed to observe the effect of added water in influencing the "tailing phenomena" observed when micro-organisms were irradiated in seafoods.

MATERIALS AND METHODS

Micro-organisms selected represent species known to be pathogenic or non-pathogenic members from genera containing pathogenic species. *Salmonella paratyphi* and *Salmonella wichita* were obtained from the culture collection maintained at the Communicable Disease Center (CDC), Atlanta, Georgia. The following species were obtained from the collection maintained in the Department of Microbiology, Oregon State University, Corvallis, and were originally obtained from the American Type Culture Collection (ATCC), Bethesda, Maryland: *Salmonella typhi*, *Salmonella paratyphi A*, *S. paratyphi B*, *Salmonella choleraesuis*, *Salmonella enteritidis*, *Salmonella pullorum*, *Shigella dysenteriae*, *Shigella paradysenteriae*, *Shigella sonnei*, *Escherichia coli*, *Streptococcus faecalis*, *Proteous vulgaris*, *Neisseria cattarrhalis* and *Mycobacterium smegmatis*. *Streptococcus pyogenes* was obtained from the local hospital following isolation from a *streptococcus* infection and *Staphylococcus aureus* was isolated from a food poisoning outbreak and was shown to be coagulase positive and salt tolerant. Hartsell's broth of the following composition was used as the recovery and enrichment medium: Tryptone, 50 g; Proteose Peptone (Difco), 5.0 g; Sodium chloride, 5.0 g; veal infusion, 100 ml and distilled water to make 1 litre. The pH was adjusted so that after autoclaving at 121°C (250°F) for 20 min it was 7.2. Hartsell's agar was prepared by adding 20.0 g of agar to 1 litre of Hartsell's broth. To maintain a uniform population an inoculum from the pure culture was transferred to 15 ml of Hartsell's broth and incubated for 24 h at 35°C (95°F). From the above culture, 1 ml was inoculated into 99 ml and again incubated as above. Two flasks were inoculated in a proportion similar to that above with cells from the latter culture. These cultures were transferred similarly into four flasks, then incubated for 24 h and pooled providing 400 ml of 24-hour-old cells. The cell population was determined with a spectrophotometer calibrated against plate counts. The final population was obtained by dilution or by varying the amount added to each sample when appropriate.

The inoculated samples were exposed in a ^{60}Co irradiator located at Oregon State University, Corvallis. The initial dosimetry as determined by the fricke ferrus sulphate method was $8.13 \times 10^5 \pm 0.35$ rad/h on the 29th January 1964. Correction for decay was determined following each exposure. **The Hartsell's broth samples were prepared as follows:** quantities of 2 ml and 5 ml from the final cell concentration (10^6 cells per millilitre) were transferred into screw cap tubes (1.0×5.0 cm). The tubes were packed and sealed into No. 2 cans and maintained at 3° to 5°C (37° to 41°F) prior to irradiation. All samples were replicated five times and each replicate plated in triplicate. Low count dilutions were plated in 15 cm (6 in) Petri dishes. Irradiated control samples were treated similarly in each experiment.

The Dungeness crabmeat (*Cancer magister*) was commercially canned in ½-lb (225-g) flat tins and contained water, salt and citric acid. The oysters (*Crassostrea gigas*), shrimp (*Pandalus jordani*) and the salmon (*Oncorhynchus kisutch*) were obtained from the commercial distributor as a fresh raw product. The crabmeat was transferred aseptically from the ½-lb cans into larger containers in a transfer chamber equipped with a germicidal ultraviolet lamp. Just prior to irradiation it was comminuted and 17 g transferred to glass vials (4 cm or 1.5 in in diameter and 6.3 cm or 2.5 in in height). Approximately 1.7×10^7 cells/ml was added to each vial and distributed with a glass rod throughout the crabmeat. The samples were held at 5°C (41°F) until irradiated. The fresh oysters, shrimp and salmon were homogenized for 3 min in a blender. Seventeen g of the homogenate was transferred into vials and inoculated as above for crabmeat and held at 5°C (41°F) until irradiated. Twenty vials fitted in a specially designed holder were irradiated simultaneously on the periphery of the high flux chamber.

The test samples irradiated in Hartsell's broth were plated in Hartsell's agar using the appropriate dilutions made with peptone water. The plates were incubated at 35°C (95°F) for 48 h or until colonies were countable. Irradiated food samples were transferred aseptically in a transfer chamber to 51 ml of sterile Hartsell's broth (1 : 3 dilution) and refrigerated until plated (usually within 2 h). All dilutions were made with sterile peptone water and the platings were done on the appropriate media. The plates were incubated at 35°C (95°F) for 48 h or until colonies were countable. At high irradiation doses, where few if any survivors were anticipated on Hartsell's agar, the samples were aseptically transferred to 100 ml of Hartsell's broth and incubated at 35°C (95°F) for a minimum of five days. After the incubation, test samples were spread on differential or selective (SS agar, bismuth sulfate agar and triple iron agar) media for a qualitative determination of survivors. All low-count samples were plated on 15 cm (6 in) plates permitting the use of a larger plating sample (usually 10 ml) and thus minimizing the difficulties associated with recognizing the colonies from the sample debris. Unirradiated and inoculated controls of all samples were routinely prepared. These were used to determine the initial inoculum of cells.

RESULTS AND DISCUSSION

The elimination of infectious and toxin-producing organisms by low-level irradiation is intended to accomplish an effect similar to low-level heat pasteurization. The main objectives in both methods were to increase storage life and remove organisms which would be pathogenic or undesirable in the product. Vegetative bacteria are sensitive to irradiation, and doses of 0.5 to 0.8 Mrad will usually affect a seven decimal reduction

of most infectious and intoxicating non-spore-forming micro-organisms.

Recent investigations have been concerned with the destruction of *Salmonella* in non-perishable dried products (Brogle *et al.*, 1957; Dyer, Anderson and Dutiyabodhi, 1966; Nickerson *et al.*, 1957; Procter *et al.*, 1953). However, investigators working with perishable products must consider not only the survival but also the growth of pathogenic and spoilage micro-organisms (Mossel, 1960). Furthermore, a dose which might inactivate the *Salmonellae* and *Shigella* would be ineffective against certain sporeformers and would not destroy completely the Staphylococci or the Streptococci which, upon storage under favourable conditions of temperature, could produce toxin.

Some idea of the magnitude of dose required may be obtained by the irradiation of naturally contaminated material. However, since the number of naturally occurring pathogenic organisms, if present, is usually very low, it has been found useful to inoculate the product to numbers of about 10^6 per gram, from pure cultures and then extrapolate to lower numbers. Most organisms show an exponential death rate when suspended in simple substrates or buffers. However, in more complex media such as a food material, a "tailing effect" occurs indicative of a greater survival than can be predicted from exponential death. Thus, the D-value cannot be applied with as much confidence, since the D-value is usually based upon an exponential death curve.

In this investigation, it was found to be detrimental to the development of the organism if incubated directly in the irradiated food. Preliminary experiments have shown that irradiated organisms in irradiated food or unirradiated organisms inoculated into irradiated foods resulted in a one-log lower recovery than if they were inoculated into a fresh food product (personal observation). Other investigators have observed that certain organisms will develop best under suboptimal conditions for growth (Alper and Gillies, 1958). Because of this effect, it was considered better practice to transfer the treated samples to unirradiated media in order to recover the greatest number of cells. Each result shown in the tables is the observation made on five replications and with each replicate being plated in triplicate with the lower dilutions being plated in 15 cm (6 in) plates instead of the usual 10 cm (4 in) size recommended and used in usual bacteriological techniques.

The environmental conditions were maintained as constant as possible, and procedures were standardized in order to make valid comparison of data.

The following conditions were maintained throughout the investigations.

(1) The approximate number of cells per gram used for inoculum was maintained constant.

(2) Contamination was carefully avoided throughout all phases of each operation.

(3) Normal atmospheric conditions were maintained throughout the investigation period.

(4) The samples and inoculum were maintained at the low temperature of 5°±1°C (41°±2°F) at all times during manipulation, except during the irradiation (ambient).

(5) The same irradiation facility was used throughout the study.

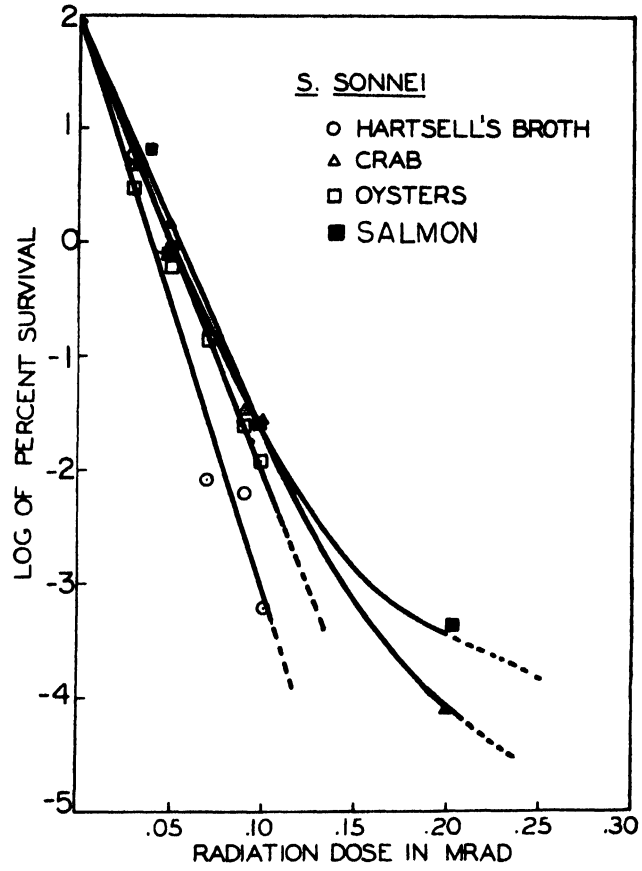


Fig 1. Irradiation inactivation pattern of Shigella sonnei *in Hartsell's broth, crab, oysters and salmon*

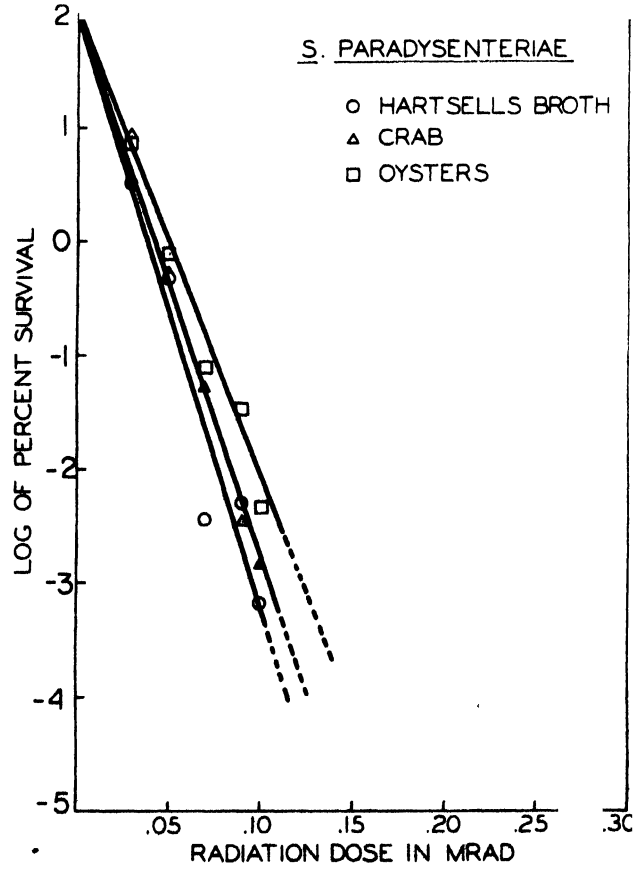


Fig 2. Irradiation inactivation pattern of Shigella paradysenteriae *in Hartsell's broth, crab and oysters*

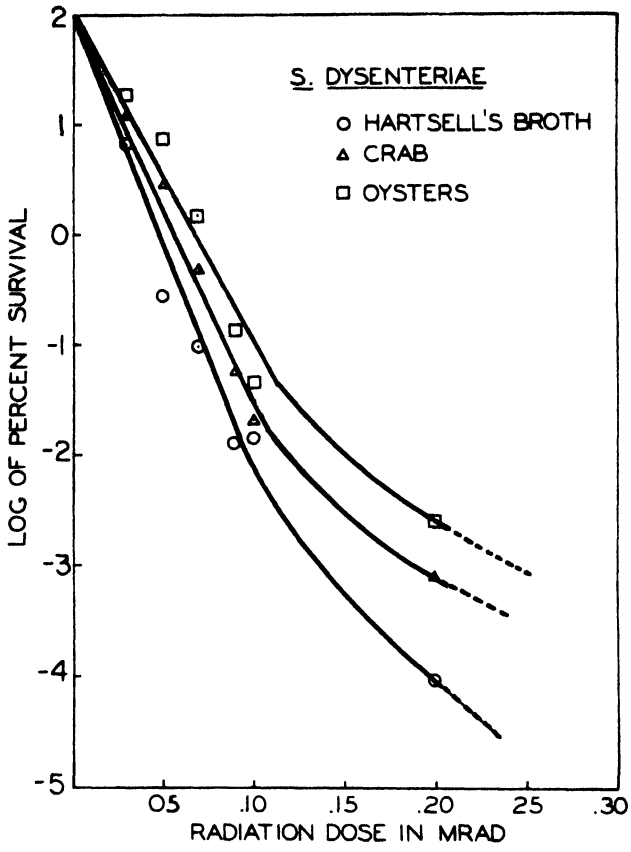


Fig 3. Irradiation inactivation pattern of Shigella dysenteriae *in Hartsell's broth, crab and oysters*

Three species of *Shigella* were studied; *Shigella dysenteriae, Shigella paradysenteriae* and *Shigella sonnei.* The most resistant species in all substrates including Hartsell's broth was *S. dysenteriae* (figs 1, 2 and 3) above 0.25 Mrad. It should also be noted that the irradiation resistance was not too different in any of the substrates including Hartsell's broth. In all cases, irradiation inactivation occurred between 0.10 and 0.25 Mrad. *Shigella dysenteriae* showed a slight "tailing effect" in all three substrates (fig 3).

The *Salmonella,* with the exception of *Salmonella enteritidis,* were considerably more irradiation resistant than the *Shigella* and somewhat less irradiation resistant than the cocci. It was also observed that *S. typhosa* (fig 4), *S. paratyphi B* (fig 5), *S. wichita* (fig 6) and *S. choleraesuis* (fig 7) appeared to be resistant in the following order in seafoods: shrimp, oysters, crab and least resistant in salmon. By the use of the simple plating techniques these micro-organisms could be recovered at 0.3 Mrad from all the seafood substrates. However, if the enrichment techniques as described in the methods above were used then *S. typhosa* (fig 4), *S. pullorum* (fig 8), *S. paratyphi* A (fig 9), *S. paratyphi* B (fig 5) and *S. wichita* (fig 6) could be recovered up to 0.9 Mrad or higher. *Salmonella enteritidis* appeared to be the least resistant of the group (fig 10). In general, the *Salmonella* were most resistant in shrimp and oysters. A marked "tailing effect" was observed for most *Salmonella* species in all the substrates tested, the only exception being *S. enteritidis* (fig 10). The results obtained are in general agreement with other investigators, ranging from a low for *S. enteritidis* of 0.10 to 0.30 Mrad in any of the substrates to a high for *S. typhosa* from 0.4 to 1.0 Mrad depending upon the substrates (Bridges and Horne, 1959; Dyer, Anderson and Dutiyabodhi, 1966; Nickerson *et al.*, 1957). Thus the *Salmonella* hold a position in some respects similar to the toxic *Clostridia* in that non-pathogenic salmonella-like organisms (*Escherichia coli*) cannot be used as test micro-organisms and irradiation pasteurization experiments with any degree of confidence.

Escherichia coli (fig 11) and *Proteus vulgaris* (fig 12) were comparable in resistance to the *Shigella.* Both were more resistant in shrimp, oysters, crab and Hartsell's broth than in salmon. *Neisseria catarrhalis* and *Mycobacterium smegmatis,* because of the difficulty in culturing, were tested only in Hartsell's broth. Their resistance was comparable to the *Salmonella.*

The most resistant of all the micro-organisms tested were the Staphylococci and Streptococci.

Streptococcus faecalis was recovered by plating technique at 0.5 Mrad without difficulty (fig 13), while *Streptococcus pyogenes* and *Staphylococcus aureus* could be recovered by the plating technique between 0.3 and 0.5 Mrad (figs 14 and 15). By the enrichment procedure, *Staphylococcus aureus* was recovered at 1.8 Mrad repeatedly, while no difficulties were experienced in

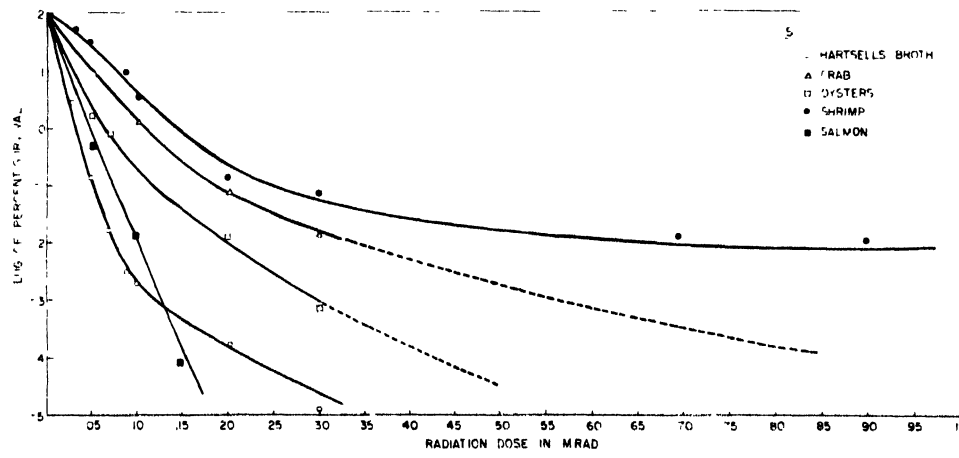


Fig 4. Irradiation inactivation pattern of Salmonella typhosa *in Hartsell's broth, crab, oysters, shrimp and salmon*

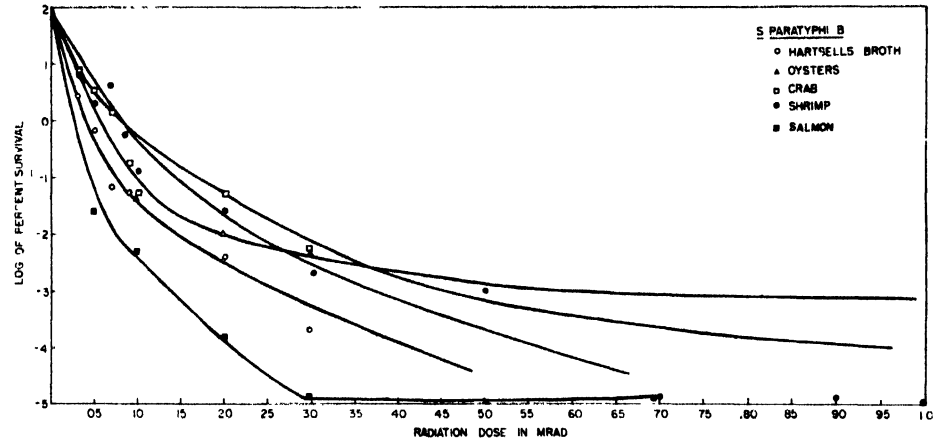


Fig 5. Irradiation inactivation pattern of Salmonella paratyphi *B in Hartsell's broth, oysters, crab, shrimp and salmon*

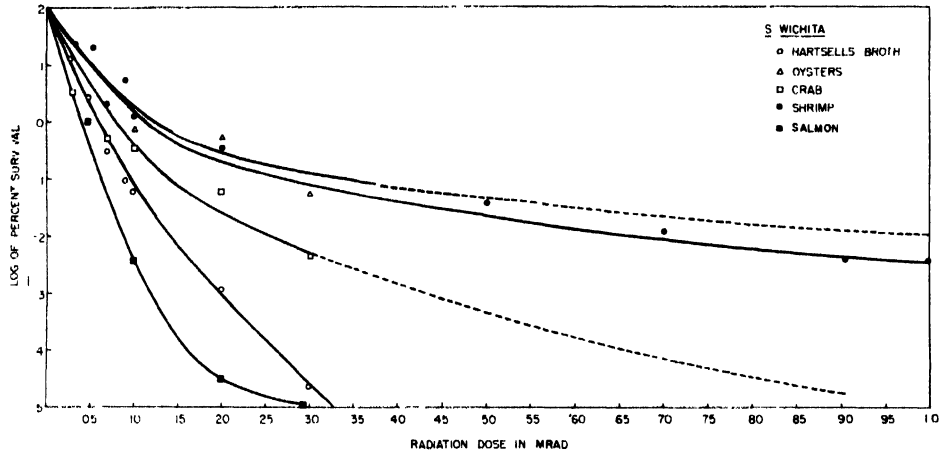


Fig 6. Irradiation inactivation pattern of Salmonella wichita *in Hartsell's broth, oysters, crab, shrimp and salmon*

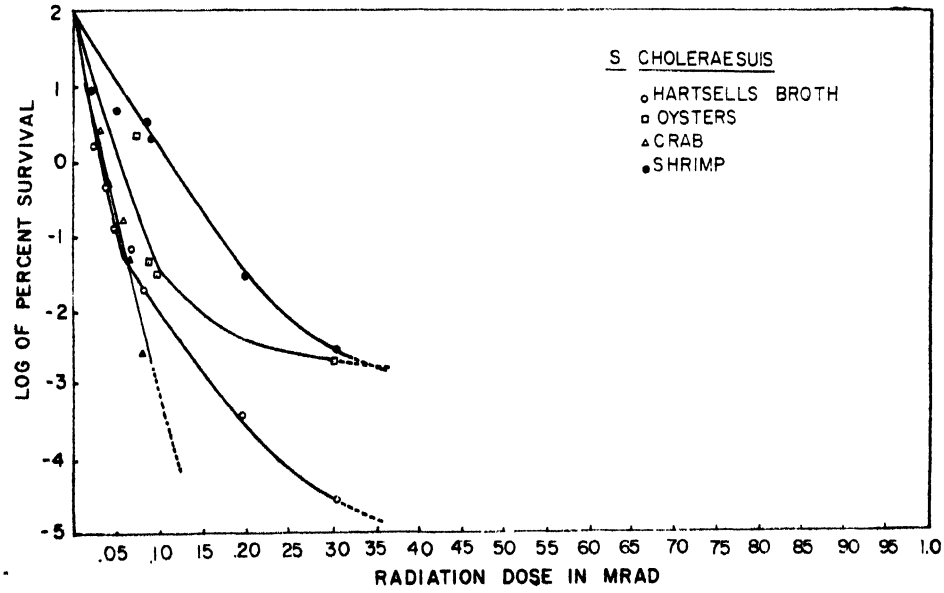


Fig 7. Irradiation inactivation pattern of Salmonella choleraesuis *in Hartsell's broth, oysters, crab and shrimp*

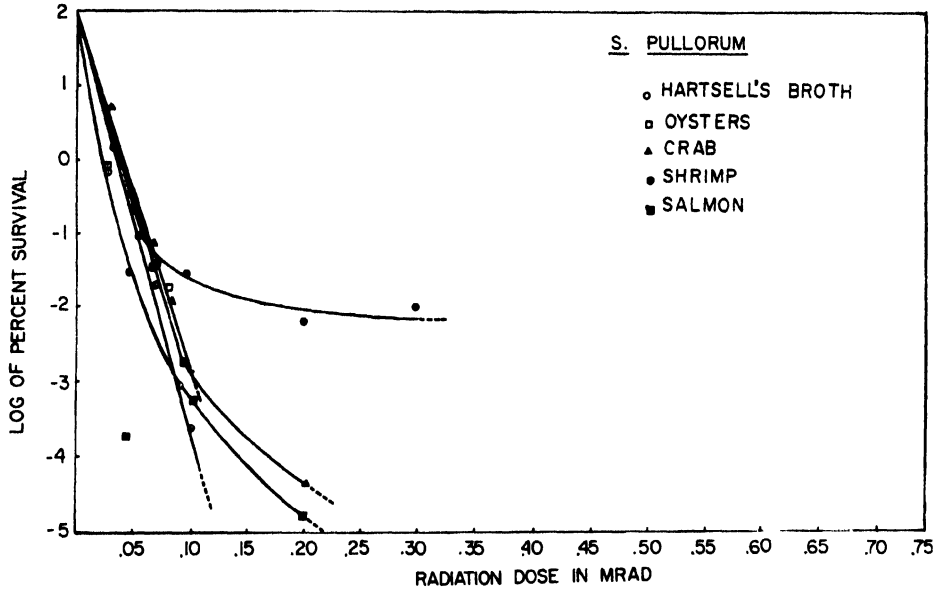


Fig 8. Irradiation inactivation pattern of Salmonella pullorum *in Hartsell's broth, oysters, crab, shrimp and salmon*

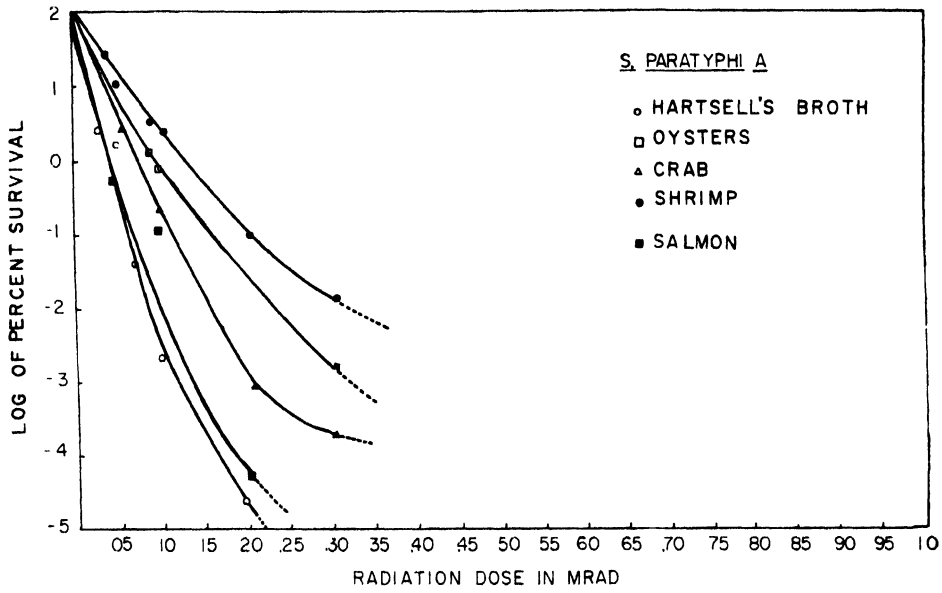


Fig 9. Irradiation inactivation pattern of Salmonella paratyphi *A in Hartsell's broth, oysters, crab, shrimp and salmon*

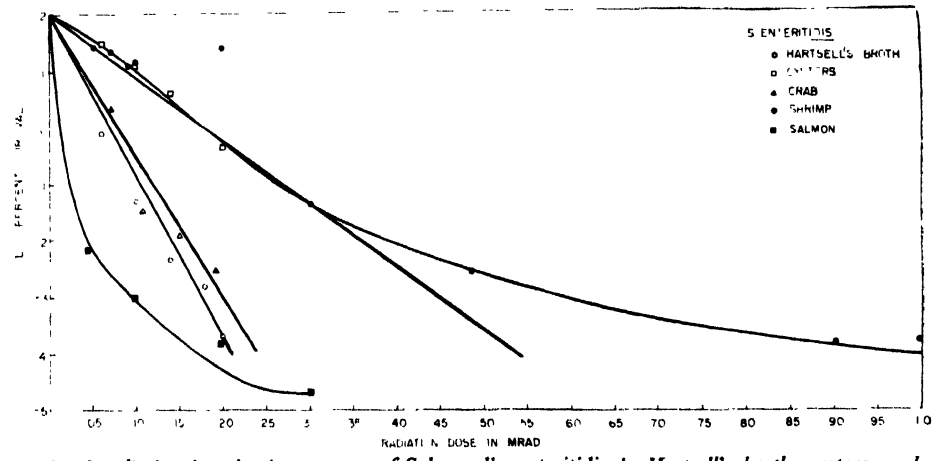


Fig 10. Irradiation inactivation pattern of Salmonella enteritidis *in Hartsell's broth, oysters, crab, shrimp and salmon*

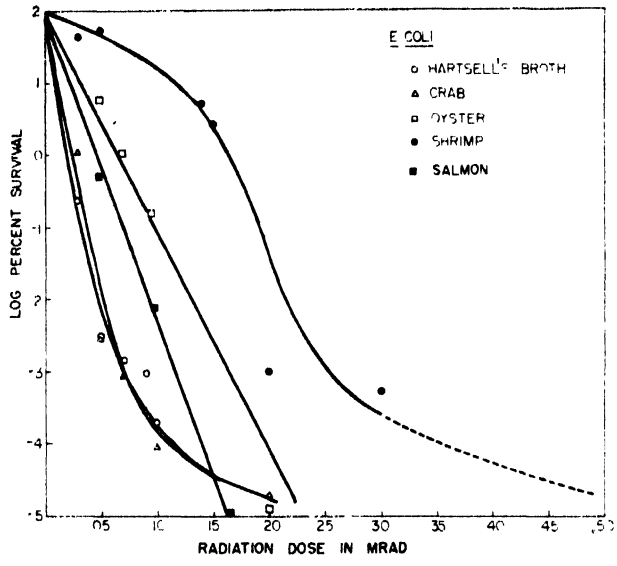


Fig 11. Irradiation inactivation pattern of Escherichia coli *in Hartsell's broth, crab, oysters, shrimp and salmon*

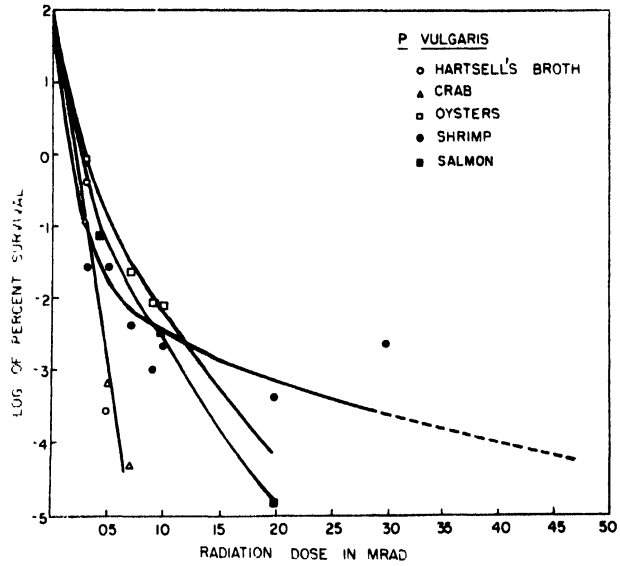


Fig 12. Irradiation inactivation pattern of Proteus vulgaris *in Hartsell's broth, crab, oysters, shrimp and salmon*

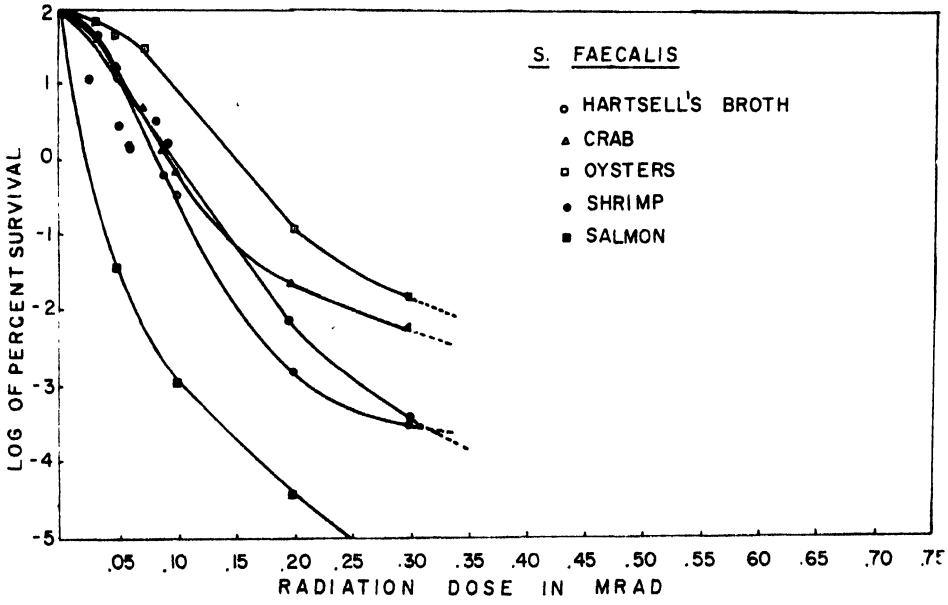


Fig 13. Irradiation inactivation pattern of Streptococcus faecalis *in Hartsell's broth, crab, oysters, shrimp and salmon*

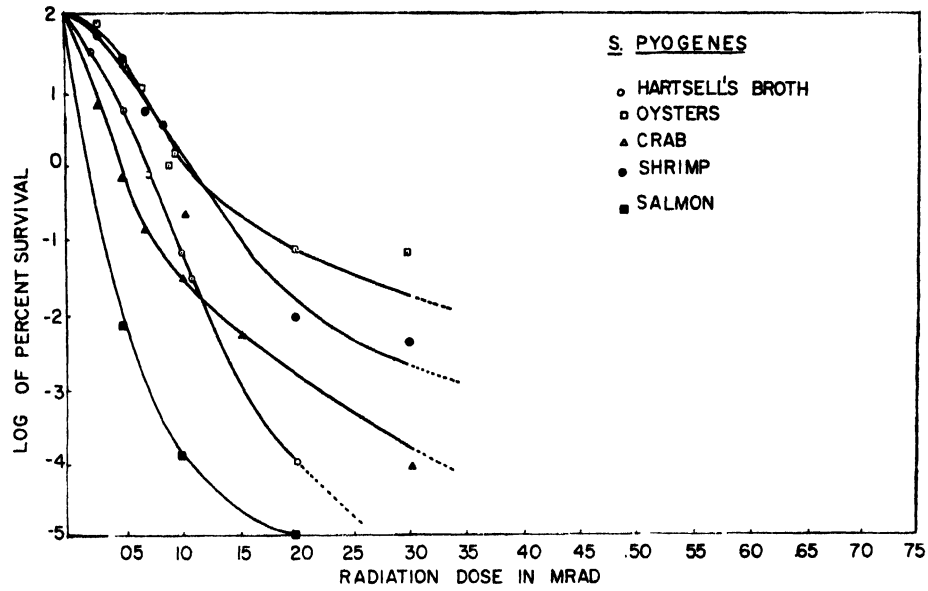


Fig 14. Irradiation inactivation pattern of Streptococcus pyogenes *in Hartsell's broth, oysters, crab, shrimp and salmon*

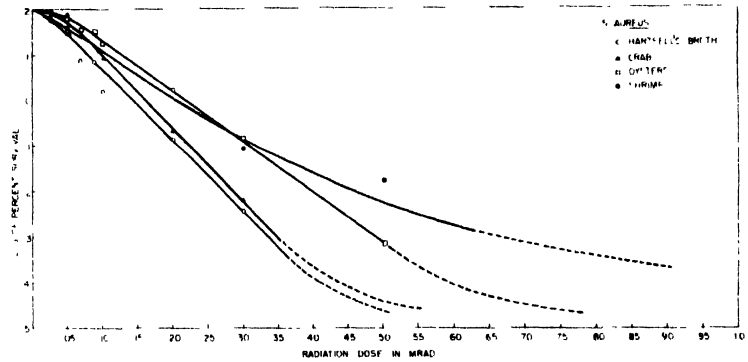


Fig 15. Irradiation inactivation pattern of Staphylococcus aureus *in Hartsell's broth, crab, oysters and shrimp*

TABLE 1. D-VALUES OF BACTERIA IN SEAFOODS AND HARTSELL'S BROTH CALCULATED BY THE SURVIVAL CURVE METHOD

*Organism**	*D-value (Mrad)*				
	Hartsell's broth	*Oysters*	*Crabmeat*	*Shrimp*	*Salmon*
E. coli	0.012	0.035	0.014	0.12	0.200
P. vulgaris	0.010	0.02	0.010	0.075	0.020
Sh. sonnei	0.020	0.025	0.027	—	0.04
Sh. paradysenteriae	0.020	0.026	0.022	—	—
Sh. dysenteriae	0.035	0.040	0.035	—	—
Strep. faecalis	0.050	0.100	0.075	0.075	0.040
Strep. pyogenes	0.045	0.105	0.050	0.075	0.040
Staph. aureus	0.080	0.150	0.080	0.190	—
Sal. pullorum	0.025	0.035	0.035	0.075	0.035
Sal. choleraesuis	0.055	0.075	0.055	0.075	—
Sal. enteritidis	0.025	0.05	0.025	0.095	0.060
Sal. paratyphi A	0.025	0.075	0.05	0.085	0.030
Sal. paratyphi B	0.055	0.100	0.100	0.100	0.100
Sal. wichita	0.045	0.075	0.087	0.100	0.050
Sal. typhosa	0.040	0.075	0.100	—	0.030

* Inoculated at the level of 1×10^8 micro-organisms per gram.

recovering *S. faecalis* and *S. pyogenes* above 1 Mrad. In all substrates a marked "tailing effect" could be observed as well as a slight "hump" at the curve origin. This "hump" could be due to the tendency of these cells to form aggregates.

Table 1 shows a range of D-values based on the survival curve methods. It is obvious that no one value fits all substrates. However, a range of value taking into account the tailing effect can be determined. It is realized that the end point method as used by Schmidt (Schmidt, 1954; Stumbo, 1948) or Stumbo would have been better for covering a wider range in inactivation. However this investigation is still in progress and it is anticipated that further work will also include such information.

SUMMARY

The survival patterns of various species of food infection micro-organisms indicate that among the infection enterics the *Salmonella* (six strains) were much more resistant as a group than were the *Shigella* (three strains) or *Escherichia coli*. The seafood used as substrates included crab, shrimp, oysters and salmon. The most resistant micro-organisms tested were *Streptococcus pyogenes* and *Staphylococcus aureus*, some of which could be recovered at 1.5 Mrad. A marked "tailing off" was observed with all species except the *Shigella*. This effect was most pronounced in the seafood and least pronounced in Hartsell's broth. The "tailing off" phenomenon varied with the substrate being very marked in crab and shrimp. The "tailing off" phenomenon cannot be explained as a mere effect of medium, but rather indicates a more complex situation. The results indicate that pasteurization doses usually based on D-values would be inaccurate, since such values are usually determined on a linear or sigmoidal inactivation curve.

References

ALPER, T and GILLIES, N E 1958 Restoration of *Escherichia coli* strain B after irradiation; its dependence on sub-optimal growth conditions. *J. gen. Microbiol.*, **18**, 461.

BROGLE, R C, NICKERSON, J T R, PROCTOR, B E, PYNE, A, CAMPBELL, C and CHARM, S 1957 Use of high-voltage cathode rays to destroy bacteria of the *Salmonella* group in white egg solids, egg yolk solids, and frozen egg yolk. *Fd Res.*, **22**, 572.

BRIDGES, B A and HORNE, T 1959 The influence of environmental factors on the microbicidal effect of ionizing radiations. *J. gen. Microbiol.*, **22**, 96.

DYER, J K, ANDERSON, A W and DUTIYABODHI, P 1966 Radiation survival of food pathogens in complex media. *Appl. Microbiol.*, **14**, 92.

MOSSEL, D A A 1960 The destruction of *Salmonella* bacteria in refrigerated liquid whole egg by gamma irradiation. *Int. J. appl. Radiat. Isotopes*, **9**, 109.

NICKERSON, J T R, CHARM, S E, BROGLE, R C, LOCKHART, E E, PROCTOR, B E and LINEWEAVER, H 1957 Use of high-voltage cathode rays to destroy bacteria of the *Salmonella* group in liquid and frozen egg white and egg white solids. *Fd Technol., Champaign*, **11**(3), 159–166.

PROCTOR, B E, JOSLYN, R P, NICKERSON, J T R and LOCKHART, E E 1953 Elimination of *Salmonella* in whole egg powder by cathode ray irradiation of egg magma prior to drying. *Fd Technol., Champaign*, **7**(7), 291–296.

SCHMIDT, C F 1954 Thermal resistance of micro-organisms. In *Antiseptics, Disinfectants, Fungicides and Sterilization*, ed. G. F. Reddish, Lea and Febiger, Philadelphia, chapter 32.

STUMBO, C R 1948 A technique for studying resistance of bacterial spores to temperature in the higher range. *Fd Technol., Champaign*, **2**(3), 228–240.

Effects of Multiple Dose of Irradiation on the Bacterial Flora of Seafoods

by J. Liston, A. M. Dollar and J. R. Matches

Effects of multiple dose of irradiation on the bacterial flora of seafoods

Pasteurizing radiation is effective in increasing the shelf life of fish held under refrigeration. Effectiveness is greatest for fresh fish with a low bacterial count and diminishes to a low level as fish become more spoiled prior to irradiation. Double dose treatments using 50+50 krad or 50 + 100 krad of fresh fish spaced at seven days give a shelf life extension equivalent to higher single dose treatments up to 300 krad. As with single dose irradiation, there is minimal extension of storage life by double dose treatment of spoiling fish and eight to ten days' normal storage in ice prior to treatment appears to represent the absolute limit of any such effects. Double dose irradiation treatment thus cannot be used to conceal the true bacterial quality of a spoiled fish. Double dose irradion shows promise as a practical technique for using a shipboard irradiator.

Effets de l'irradiation à doses multiples sur la flore bactérienne des aliments d'origine marine

L'irradiation pasteurisante augmente la durée de conservation du poisson maintenu en réfrigération. L'efficacité de ce traitement maximum pour le poisson frais à faible numération bactérienne et diminue sensiblement dans la mesure où le poisson a été plus altéré avant l'irradiation. Des traitements à double dose utilisant 50+50 krad ou 50+100 krad pour du poisson frais, à des intervalles de sept jours, augmentent la durée de conservation dans une mesure égale à celle des traitements à dose unique jusqu'à 300 krad. Comme c'est le cas pour l'irradiation à dose unique, l'augmentation de la durée de conservation est minime si le traitement à double dose est effectué sur du poisson en cours de décomposition et il semble qu'un entreposage normal de huit à dix jours dans la glace avant le traitement soit la limite maximale tolérable. Par conséquent l'irradiation à double dose ne saurait être utilisée pour dissimuler la véritable qualité bactérienne d'un poisson en décomposition. L'irradiation à double dose semble être cependant prometteuse en tant que méthode pratique pour l'emploi des appareillages irradiateurs à bord des bateaux.

Efectos de la irradiación de dosis múltiples en la flora bacteriana de los alimentos de origen marino

La radiación pasterizante es eficaz para aumentar la conservación del pescado refrigerado. Tal eficacia es mayor en el pescado fresco con bajo contenido bacteriano y desciende a un bajo nivel a medida que el pescado se deteriora antes de la irradiación. Los tratamientos con dosis dobles empleando 50+50 krad ó 50+100 krad en pescado fresco, espaciadas en siete días, dan un aumento del tiempo de conservación equivalente a un tratamiento con una sola dosis más elevada de hasta 300 krad. Lo mismo que en el caso de la irradiación mediante dosis simple, hay un aumento mínimo del tiempo de conservación con un tratamiento de doble dosis del pescado en fase de deterioro, y 8–10 días de almacenamiento normal con hielo antes del tratamiento parece representar el límite absoluto de tales efectos. Así pues, el tratamiento por irradiación mediante dosis doble no sirve para ocultar la auténtica calidad bacteriana de un pescado deteriorado. La irradiación con dosis doble es prometedora como técnica práctica aplicable con un irradiador a bordo del barco.

WORK in a number of laboratories over the past 10 years has confirmed the effectiveness of pasteurizing doses of radiation in prolonging the shelf life of fishery products held under refrigeration, Masurovsky, Goldblith and Nickerson, (1963); Spinelli *et al.* (1965). Fish fillets and crabmeat respond well to doses in the range 100–500 krad and remain in good edible condition for periods in excess of 30 days after such treatment if held at temperatures in the region of 0° to 5°C (32° to 41°F). The actual extension of shelf life is dependent on the level of dose and the condition of the fish at the time of treatment. Experiments in our laboratories in which pure cultures of bacteria were irradiated at various stages of the growth cycle have shown clearly that sensitivity is greatest during the phase of active growth. Consequently, it seemed possible that an enhancement of the radiation effect might be obtained by subjecting fish to a double dose treatment spacing the second dose so that it would affect the bacterial population growing out after the primary dose while they are in a sensitive stage.

EXPERIMENTAL METHODS

Sample preparation

English sole (*Parophrys vetalus*) were caught in Puget Sound by the College of Fisheries research vessel. The fish were iced while still alive and immediately transported to the laboratory. The fish were held in iced storage before filleting and use.

In experiment 1 fish were held in iced storage for 2 days after catch. This storage time was extended to eight and 16 days in experiments 2 and 3 respectively, as shown in Table 1. On the day of use the fish were removed from iced storage, filleted and the fillets distributed in 45-g quantities in polymylar pouches. The pouches were sealed, irradiated and stored at 1.1°C (34°F). Samples to be given a second irradiation treatment were irradiated and immediately returned to storage. The time between initial and second dose was varied for each experiment to determine the effects of different spacing intervals. The irradiated fillets were held seven days between treatments in experiment 1. In experiments 2 and 3 the storage time was 3, 7, 14 and 17 days and 2, 5 and 7 days respectively.

TABLE 1. TIME OF STORAGE AND IRRADIATION

	Days whole fish held in iced storage before use	*Time between initial and second dose, days*
Experiment 1	2	7
Experiment 2	8	3, 7, 14, 17
Experiment 3	16	2, 5, 7

Radiation

The packaged English sole fillets were irradiated with single doses of 100, 150, 200 and 300 krad and with multiple doses of 50 + 50, 50+100, 100+100 and 100+200 krad. Gamma radiation treatments were given in the Cobalt-60 Mark II food irradiator located in the

College of Fisheries, University of Washington, at a dose rate of 300 krad per hour.

Sampling

Sampling was performed by homogenizing the entire contents of the pouch with 180 ml of 0.1 per cent peptone water for 1 to 1½ min at high speed in a Waring blendor. Serial decimal dilutions were prepared in 0.1 per cent peptone water and total viable counts of the mixed flora were obtained by the pour place method using TPY agar (Trypticase, 15 g; phytone, 5 g; yeast extract, 5 g; NaCl, 5 g; Agar, 15 g; water, 1 litre; pH adjusted to 7.2±0.1) (Miyauchi *et al.*, 1963) and an incubation temperature of 22°C (72°F).

RESULTS

Counts from English sole fillets stored at 1.1°C (34°F) after single and double irradiation treatments starting two days in ice after capture were averaged and analysed statistically. The changes in bacterial numbers are shown in figs 1 and 2 where regression lines have been fitted to the averaged points using the method of least squares. Each point represents an average value for four samples with duplicate determinations. There is a clear difference between the rate of increase of bacterial numbers in the single- and double-treated samples at the 100 krad and 150 krad levels indicating that the double dose is more effective than a comparable single-dose treatment. At the higher levels of 200 and 300 krad the effect is not nearly so marked. There is a just detectable difference at 200 krad but no difference at 300 krad.

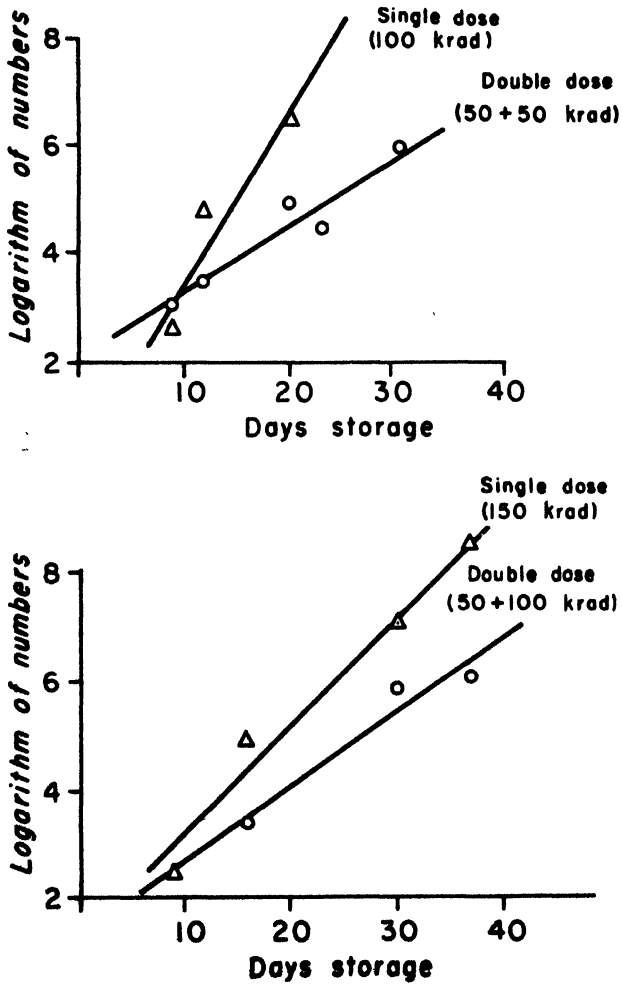


Fig 1. Increases in numbers of bacteria per gram of English sole fillets stored at 1.1°C (34°F) after single and multiple doses of 100 and 150 krad (fitted regression lines)

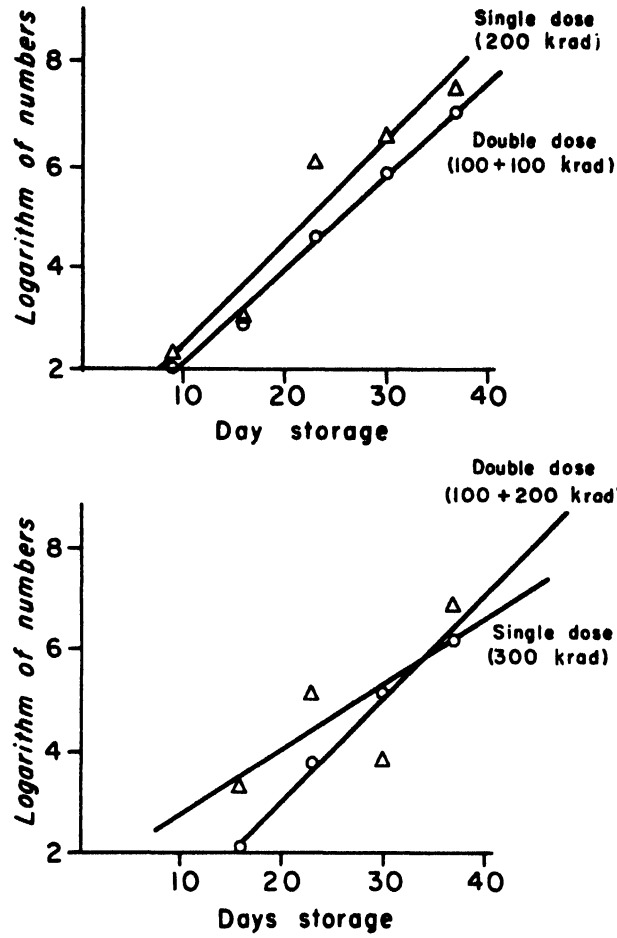


Fig 2. Increases in numbers of bacteria per gram of English sole fillets stored at 1.1°C (34°F) after single and multiple doses of 200 and 300 krad (fitted regression lines)

Using the same technique of fitted regression lines the times taken to reach 10^5, 10^6 and 10^7 bacteria/g fillet tissue have been plotted in fig 3 for single doses and in fig 4 for the comparable multiple doses. It is common practice in the food industry to accept a level of 10^6 organisms/g as indicating a spoiled product. However, a number of workers have noted that irradiated fish products are still of good edible quality when the count is one or two orders of magnitude greater than this. There was a steady increase in the time required for the count to attain each level as dose was increased in single-dose experiments. Thus it required about 15 and 18 days respectively for one 100 krad dose, 25 and 35 days after 200 krad and 35 to >40 days after 300 krad to reach 10^6 and 10^7 respectively. Multiple-dose treatments yielded curves which are almost parallel with the dose axis for 10^6 and 10^7 counts. All dose treatments showed a delay of about 40 days before a count of 10^7/g was obtained and 10^6/g was reached between 30 and 35 days in all cases. These results imply that from the practical point of view a

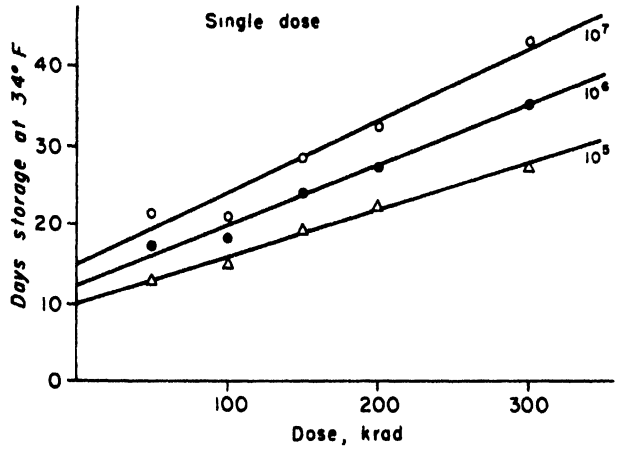


Fig 3. Times after various single irradiation doses for numbers of bacteria to reach 10^5, 10^6 and 10^7 cells per gram of English sole fillets stored at 1.1°C (34°F) (fitted regression lines)

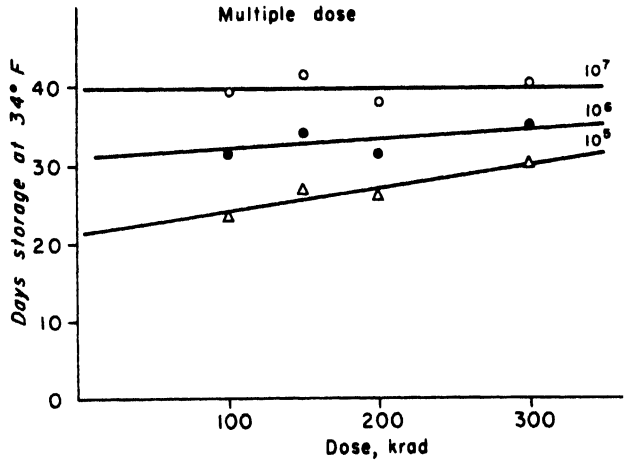


Fig 4. Times after various multiple irradiation doses for numbers of bacteria to reach 10^5, 10^6 and 10^7 cells per gram of English sole fillets stored at 1.1°C (34°F) (fitted regression lines)

minimum double-dose treatment of 50+50 krad, spaced at a seven-day interval, is as effective as single doses up to 300 krad. However, in this experiment taste evaluations indicated that eating quality was retained better by the slightly higher double treatment, 50+100 krad, and this was therefore selected for further experiment.

From previous work it was obvious that the effectiveness of irradiation is greatly dependent on antecedant storage experience of the fish and experiments were therefore carried out to determine the extent to which prior storage would reduce the utility of double irradiation.

Table 2 shows bacterial counts results for fish held eight days in ice and then irradiated singly at 150 krad and at 50 krad followed by a 100 krad second irradiation after 3, 7, 14 and 17 additional days storage. Single-dose samples yielded unacceptable count levels after about 25 days total storage; a few days less than for two-day iced fish. Double irradiation at three days (11-day total) produced a reduction in count but only a few days extension of acceptability. A second irradiation after 7 (15), 14 (22) and 17 (25) days produced hardly detectable count reductions and little if any shelf life extension.

TABLE 2. EFFECTS OF MULTIPLE DOSES OF IRRADIATION ON BACTERIA ON ENGLISH SOLE FILLETS TAKEN FROM FISH STORED IN ICE 8 DAYS (LOGARITHMS OF BACTERIA PER G)

Dose	*Days' storage at 0°C (32°F)*						
(krad)	0	3	7	14	17	27	34
0	4.08	5.52	7.58	7.87	7.52	7.28	—
50	2.34	3.28	4.56	6.45	7.81	8.52	8.46
150	1.40	—	3.38	—	6.78	8.08	8.25
50+100	—	2.18*	—	5.68	6.08	7.60	7.84
50+100	—	—	4.25*	6.57	6.30	8.45	7.81
50+100	—	—	—	6.32*	6.84	6.84	7.52
50+100	—	—	—	—	6.84*	7.34	6.53

* Count after second dose of 100 krad.

TABLE 3. EFFECTS OF MULTIPLE DOSES OF IRRADIATION ON BACTERIA ON ENGLISH SOLE FILLETS TAKEN FROM FISH STORED IN ICE 16 DAYS (LOGARITHMS OF BACTERIA PER GRAM)

Dose	*Days' storage at 4°C (39.2°F)*			
(krad)	0	2	5	7
0	5.52	7.48	7.96	8.11
50	4.74	5.53	7.48	8.15
100	4.95	5.20	7.58	7.66
150	5.43	4.87	7.38	7.59
50+100	—	5.51*	6.81	7.53
50+100	—	—	7.63*	7.26
50+100	—	—	—	7.20*

* Count after second dose of 100 krad.

Results for fish held 16 days in ice prior to a similar single- and double-dose treatment are shown in Table 3. In this case all samples were spoiled between 18 and 21 days' total storage and the effect of a single- and double-dose treatments was limited to a delay of two to three days in attainment of unacceptable count levels. It is noteworthy that little immediate reduction in count resulted from either single or double irradiation in any case.

The results from the 8-day and 16-day iced fish experiments confirm that double irradiation is not an effective method for falsification of fresh fish quality since high-count fish show little reduction in count after irradiation and count increase is delayed for perhaps three days at most.

DISCUSSION

The practical implementation of radiation pasteurization as a commercial process is dependent on feasibility and cost as well as on safety and effectiveness. Effectiveness is well established and there is little real question of safety. Feasibility depends on how well the process can be fitted into existing fish handling procedures and cost is related to this and to the price and operational expense of equipment.

Since our studies have confirmed that radiation is most effective when applied to very fresh fish it would seem logical that shipboard irradiators should be used where possible. Obviously at normal fishing rates throughput of material could represent a problem in this situation. Therefore, the lower the effective dose the better. It is proposed, on the basis of the results obtained in these experiments, that a primary dose of 50 krad be given at sea followed by a secondary dose of 100 krad onshore approximately seven days after the primary treatment. Preliminary experiments in which whole fish were

irradiated at 50 krad, held in ice, filleted and stored after a second 100 krad irradiation have yielded encouraging results. These experiments are continuing.

The effectiveness of double irradiation seems to depend on the condition of the bacteria surviving the primary treatment. These bacteria become most sensitive as they move into a stage of active growth and this appears to take between five and nine days at storage temperatures near 0°C (32°F). Apparently after growth has proceeded to a certain point either without treatment or after primary radiation, the effect of a second (or delayed first) dose is minimal. This may be due to the increased number of bacteria existing in the stationary phase of growth or to the distribution of bacteria throughout the fish tissues. From the practical point of view this implies that double irradiation is effective for extending shelf life of fresh fish but ineffective as a means of deluding the consumer about the quality of spoiled fish.

Previous experiments with pure cultures of bacteria have indicated no significant build-up of radiation-resistant types as a result of multiple-dose treatments. There is thus little likelihood that this would present a significant problem in practice. Multiple treatments have not produced any overt additional flavour or odour changes in the products tested. However, obviously this point should be investigated more thoroughly.

References

MASUROVSKY, E G, GOLDBLITH, S A and NICKERSON, J T B
1963 Effects of substerilization doses of ^{60}Co gamma radiation on the cold storage life extension of shucked soft-shelled clams and haddock fillets. *Appl. Microbiol.*, **11**, 220.

MIYAUCHI, D, EKLUND, M, SPINELLI, J and STOLL, N Applica-
1963 tion of radiation-pasteurization processes to Pacific crab and flounder. Isotopes-Industrial Technology TID 4500, *Report TID* 19585, 19th ed., Office of Technical Services, Dept. of Comm., Washington.

SPINELLI, J, EKLUND, M, STOLL, N and MIYAUCHI, D
1965 Irradiation preservation of Pacific Coast fish and shellfish. III. Storage life of Petrale sole fillets at 33°F and 42°F. *Fd Technol., Champaign*, **19**, 1016.

Irradiation Cleavage of Trimethylamine Oxide in Fish Muscle

by K. Amano and H. Tozawa

Irradiation cleavage of trimethylamine oxide in fish muscle

Since little has been known about the change of trimethylamine oxide (TMAO) in fish caused by irradiation, the decomposition products from TMAO by irradiation were studied from the viewpoints of both quality changes and wholesomeness.

By gamma irradiation at dosages from 0.6 to 5.6 Mrad, formations of trimethylamine (TMA), dimethylamine (DMA), ammonia and formaldehyde (FA) were demonstrated in the flesh of fish rich in TMAO. The amounts of these decomposition products differed with given dosage and with the species of fish treated. However, quantities of each compound were not large enough to raise the question of wholesomeness. Only the gadoid group indicated relatively higher levels of DMA and FA than other species such as shark (*Deania* spp.) and squid (*Sepiotenthis lessonia*).

It may be concluded that the precursor of DMA and FA should be TMAO in marine fish, but ammonia may be derived from some nitrogenous compounds other than TMAO. In ordinary fish of the marine type, various substances could be precursors of FA, but in the particular case of the gadoid fishes TMAO will be most likely to form FA on irradiation, since irradiation appears to enhance the biological production of FA and DMA from TMAO, as discovered by the author in 1964. As the coexistence of TMAO and the enzyme system is found the free radicals generated by irradiation may play a significant role in this specific enhancement.

Séparation par irradiation de l'oxyde de triméthylamine dans le muscle de poisson

Etant donné que l'on connaissait mal les modifications de la teneur en oxyde de triméthylamine (OTMA) du poisson sous l'effet de l'irradiation, les produits de la décomposition de l'OTMA par l'irradiation ont été étudiés sous l'angle tant de la modification de la qualité que de l'innocuité.

L'irradiation aux rayons gamma à des doses variant de 0,6 à 5,6 Mrad a révélé la formation de triméthylamine (TMA), de diméthylamine (DMA), d'ammoniac et de formaldéhyde (FA) dans la chair du poisson riche en oxyde de triméthylamine. Pour ces divers produits de décomposition, les quantités variaient avec la dose d'irradiation et avec l'espèce de poisson traitée, mais dans aucun cas n'atteignaient un niveau tel que soit mise en question la comestibilité du produit. Seuls les Gadidés ont révélé des niveaux de DMA et de FA comparativement plus élevés que d'autres espèces, comme les requins (*Deania* spp.) et le calmar (*Sepiotenthis lessonia*).

On pourrait en conclure que dans les poissons marins la DMA et le FA dérivent de l'oxyde de triméthylamine (OTMA), mais l'ammoniac peut provenir de composés azotés autres que l'OTAM. Dans les poissons marins courants, diverses substances pourraient donner naissance au formaldéhyde mais dans le cas particulier des Gadidés, l'OTMA donnera probablement du formaldéhyde à la suite d'une irradiation, celleci paraissant renforcer la production biologique de FA et de DMA à partir d'OTMA, comme l'auteur l'a établi en 1964. Etant donné que l'oxyde de triméthylamine et le système enzymatique sont présents simultanément, il se peut que les radicaux libres produits par l'irradiation jouent un rôle important dans cette action spécifique de potentialisation.

Descomposición del oxido de trimetilamina en el tejido muscular del pez, por irradiación

Como no se conocen bien los cambios que se producen por irradiación en el óxido de trimetilamina de los peces se han estudiado los productos de descomposición de dicho óxido provocados por la irradiación, desde los puntos de vista de los cambios de la calidad y de la sanidad del producto.

Se ha demostrado la formación de trimetilamina (TMA), dimetilamina (DMA), amoníaco y formaldehido (FA) en la carne del pez rica en óxido de trimetilamina bajo la acción de los rayos gamma en dosis de 0,6 a 5,6 Mrad. Las cantidades de estos productos de descomposición dependen de la dosis irradiada y de la especie del pez: no obstante, las cantidades de cada compuesto no eran lo suficientemente grandes para plantear la cuestión de la sanidad. Solamente el grupo de los gadoideos indicó niveles de DMA y de FA superiores a los de otras especies, como escualos (*Deania* spp.) y calamares (*Sepiotenthis lessonia*).

Puede llegarse a la conclusión de que el precursor de DMA y FA debe ser, en los peces marinos, el óxido de trimetilamina, aunque el amoníaco puede también formarse de algunos otros compuestos nitrogenados. En los peces ordinarios del tipo marino pueden ser precursores del FA varias sustancias, pero, en el caso particular de los gadoideos, lo más probable es que el óxido de trimetilamina forme, por irradiación, formaldehido, puesto que ésta aumenta la producción biológica de FA y DMA a partir del óxido de trimetilamina, como descubrió el autor en 1964. Dada la coexistencia del óxido de trimetilamina y del sistema de enzimas, los radicales libres generados por irradiación pueden desempeñar una importante función en esta acción específica.

TRIMETHYLAMINE OXIDE has been noted as a possible precursor of formaldehyde and dimethylamine, under the effect of heat treatment (Hattori and Hasebe, 1937), reducing agents like sulfites (Soudan, 1959), or specific enzymes of certain marine fish (Amano and Yamada, 1964). These findings have led the writers to anticipate the occurrence of a similar reaction in trimethylamine oxide (TMAO) by ionizing radiation.

Although much work has been carried out on the effect of irradiation on various food components such as protein, amino acids, lipids, carbohydrates and vitamins, very little has been studied on the fate of TMAO by irradiation. As it is widely distributed in marine species of fish and shellfish, the decomposition products of TMAO due to irradiation should be interesting from both a quality and freshness standpoint, when a practical application of irradiation to fish products is considered.

The present paper also deals with the formations of ammonia, amines and formaldehyde (FA) in some fish of marine origin with special emphasis on the decomposition products of TMAO under ionizing radiation.

EXPERIMENTAL METHODS

Species of fish irradiated

The species of fish known for their rich content of TMAO were chosen; Alaska pollack (*Theragra chalcogramma*), cod (*Gadus macrocephalus*), a squid (*Sepiotenthis lessonia*) and a variety of shark (*Deania* spp.). These fishes were frozen in dry ice immediately after catching and stored in a freezer at −80°C (−112°F) until used.

Preparation and irradiation of samples

Flesh portions, excluding dark muscle, were removed from the fish while they were in a semi-defrosted condition

and ground through a meat grinder. Each 10-g portion was placed in a bag of aluminium foil laminated with polyethylene (4×5 cm) and sealed under vacuum (about 6 mmHg). These bags were irradiated at a distance of 7 to 22 cm from a ^{60}Co source with 550 ci for 37 h at 0±2°C (28.4° to 35.6°F). The dosage obtained under these conditions was in a range from 0.6 to 5.6 Mrad.

TMAO solution

As a pure specimen of TMAO, 0.1 N TMAO solution in M/10 phosphate buffer (pH 6.0) was prepared and subjected to irradiation after it was sealed in the aluminium bags as mentioned above.

Determinations of TMAO, TMA (trimethylamine), DMA (dimethylamine), ammonia and FA

To each 10.0-g portion of the irradiated fish flesh was added 20 ml of 10 per cent trichloroacetic acid (TCA). The TCA extracts thus obtained were divided into equal quantities in the respective determinations. Volatile basic nitrogen was determined by a Conway unit. TMAO was converted into TMA by titanium trichloride (Bystedt, 1959) and subsequently determined as TMA, and TMA and ammonia, by the method described by Hayashi and Unemoto (1961). DMA was determined by the copper dithiocarbamate method (Dyer and Mounsky, 1945) and FA by a modified Nash's method (1953).

Preparation of the test mixtures and the determination of DMA formation as a result of irradiation

The experiments under this heading were intended to elucidate the formation of an exceptionally large quantity of DMA, and consequently FA, when cod species were irradiated, and were carried out as follows:

White flesh portion of cod, plus an homogenate of cod pyloric caeca (5 per cent). Irradiation at 0.6 and 3 Mrad. DMA was determined from the mixture.

Non-irradiated cod flesh plus irradiated homogenate of cod pyloric caeca (5 per cent). No irradiation was conducted after mixing. DMA was determined after standing for 23 h at 0° and 10°C (32° and 50°F).

Irradiated cod flesh plus irradiated or non-irradiated homogenate of cod pyloric caeca (5 per cent). No irradiation was done afterwards and DMA was determined on each mixture.

M/5 TMAO solution in M/10 phosphate buffer (pH 6.0) plus equal quantities of the homogenate of cod pyloric caeca were irradiated. The final concentration of TMAO in the mixture was M/10 and pyloric caeca content was 5 per cent. Pyloric caeca, heat processed at 100°C (212°F) for 15 min, was also tested as a control. Irradiation dosage given was 3.0 Mrad.

RESULTS

TMAO content of the fish samples

Table 1 indicates the content of TMAO and volatile basic nitrogen in the fish samples before the treatment of irradiation.

Amines

A remarkable production of TMA and DMA was demonstrated by the irradiation in both TMAO solution and fish flesh as shown in figs 1 and 2. The amount of TMA formed in fish flesh was far smaller than that in the TMAO solution and did not show an increase parallel with the dosage, as seen in a TMAO solution. The difference in the quantity of TMA formed was not great among the species of fish.

A considerable difference was noted in DMA formation among the species. The cod group, particularly Alaska pollack, produced a higher amount of DMA than shark or squid. It should also be noted that the DMA amount generated in Alaska pollack was much larger than in the TMAO solution.

TABLE 1. CONTENT OF TMAO AND VOLATILE BASIC NITROGEN IN THE FISH SAMPLES BEFORE THE TREATMENT OF IRRADIATION

	Alaska pollack (A)	*Alaska pollack (B)*	*Cod (A)*	*Cod (B)*	*Squid*	*Shark*
	(mg%)	*(mg%)*	*(mg%)*	*(mg%)*	*(mg%)*	*(mg%)*
TMAO-N	131	125	105	109	88	276
Volatile basic N	12.6	10.0	12.3	13.2	20.6	11.5

Remark: content of TMAO-nitrogen in 0.1 N TMAO solution in M/10 phosphate buffer (pH 6.0) was 140 mg per cent.

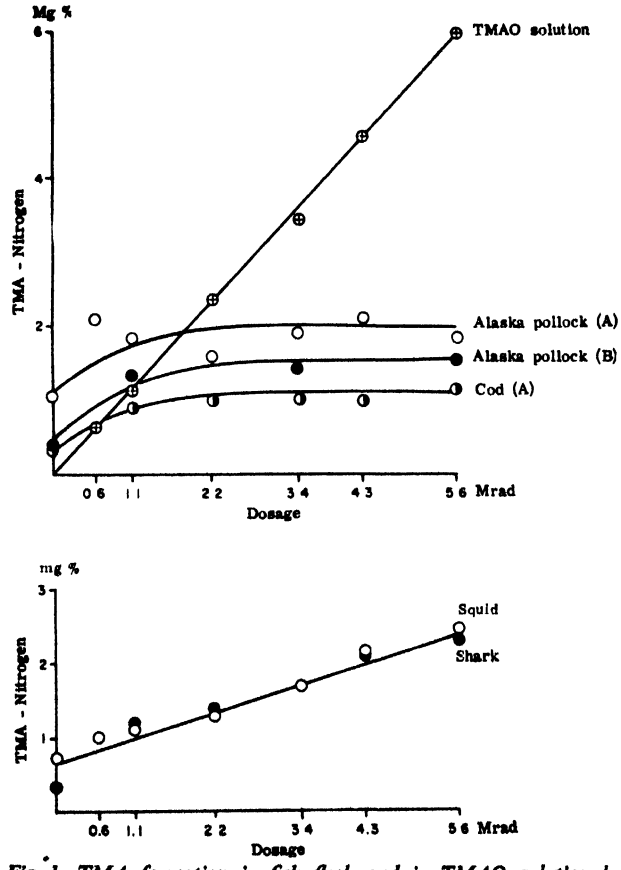


Fig 1. TMA formation in fish flesh and in TMAO solution by irradiation

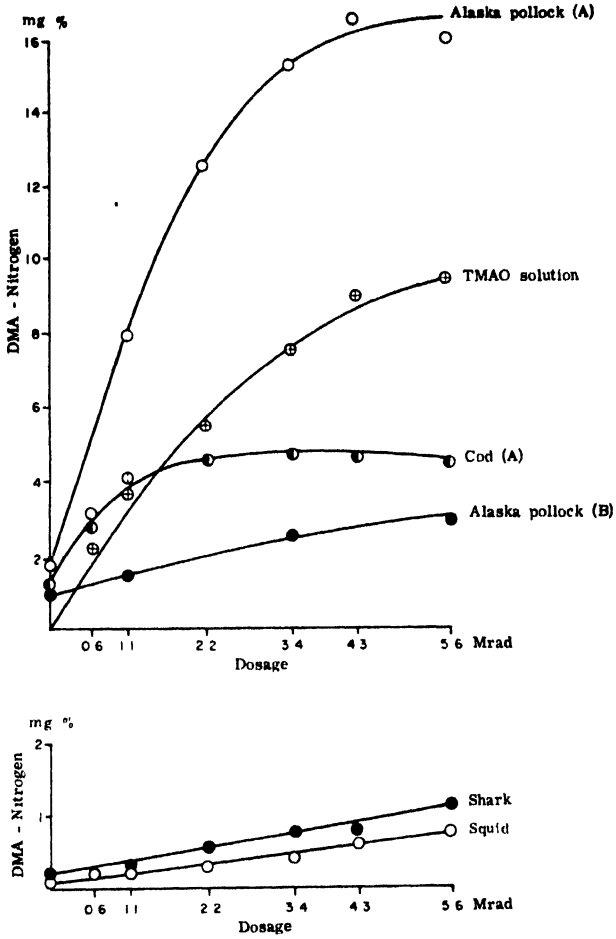


Fig 2. DMA formation in fish flesh and in TMAO solution by irradiation

The quantity of TMA and DMA formed by irradiation with an equal dose level (3.4 Mrad) was variable with the species and the samples of the same species. In cod flesh and TMAO solution, DMA formation was larger than that of TMA, conversely so was the amount in shark and squid (table 2). Carp flesh was almost lacking in TMAO when irradiated at 3 Mrad. It showed only traces of either TMA or DMA.

Ammonia

Ammonia was formed by irradiation in fish flesh, while it was not demonstrated in TMAO solution (table 3). It is interesting to note that ammonia can be formed in carp (*Cyprinus carpio*) flesh in the quantities equivalent to marine fish. This finding may suggest a possibility that some nitrogenous substances other than TMAO is responsible for the radiation formation of ammonia.

TABLE 3. INCREMENT IN THE AMOUNT OF AMMONIA IN THE SAMPLES BEFORE AND AFTER IRRADIATION

Species	*Dosage (Mrad)*					
	0.6	1.1	2.2	3.4	4.3	5.6
TMAO solution	0.1		0.1		0.1	0.1
Alaska pollack (A)	0.9	1.3	1.7	2.3	3.1	3.8
Alaska pollack (B)		1.1		2.7		3.7
Cod	1.0	1.3	1.9	2.9	4.4	4.8
Shark		1.0	1.8	2.3	2.8	3.2
Squid	2.1	1.8	2.5	2.9	3.4	5.1
Carp*				2.1*		

* In the case of carp flesh a dosage of 3.0 Mrad was given.

Formaldehyde

Because of its highly reactive nature with protein, or many other compounds in fish tissues, a full determination of FA may not be feasible, but FA formation was confirmed in all irradiated flesh samples of the fish examined. The pattern of FA formation in relation to the given dosages showed some resemblance to that of DMA formation (fig 3) in fish flesh. However, it was quite different in case of TMAO solution, where FA formation tended to decrease after the dose level reached a certain degree.

FA formation in carp flesh, on the other hand, indicated a level of 1.0 mg per cent after irradiation at 3 Mrad. This would imply some other complicated processes in the formation of FA by irradiation than from amines.

Enhancement of DMA formation in irradiated cod flesh

The irradiated mixture of cod flesh and its pyloric caeca formed a large amount of DMA, while only a slight

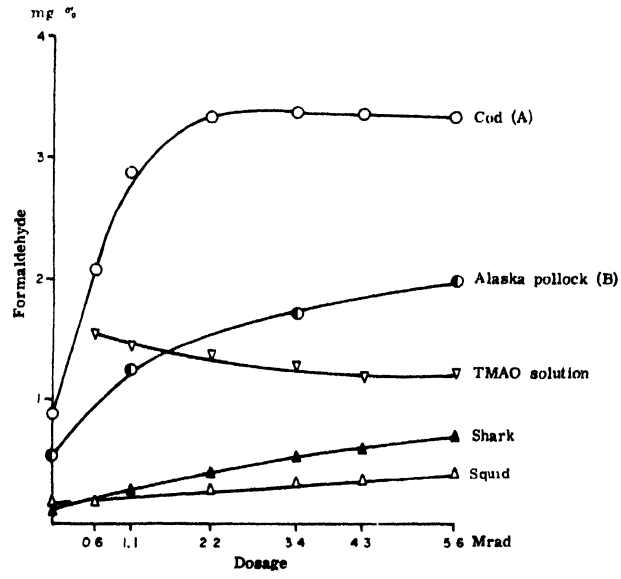


Fig 3. FA formation in fish flesh and in TMAO solution by irradiation

TABLE 2. QUANTITIES OF TMA AND DMA PRODUCED IN THE SAMPLES OF FISH AFTER IRRADIATION AT 3.4 MRAD

	TMAO solution (mg%)	*Alaska pollack (A)* (mg%)	*Alaska pollack (B)* (mg%)	*Cod (A)* (mg%)	*Squid* (mg%)	*Shark* (mg%)
DMA	7.5	15.3	2.5	4.7	0.4	0.7
TMA	3.4	1.8	1.4	1.1	1.7	1.7

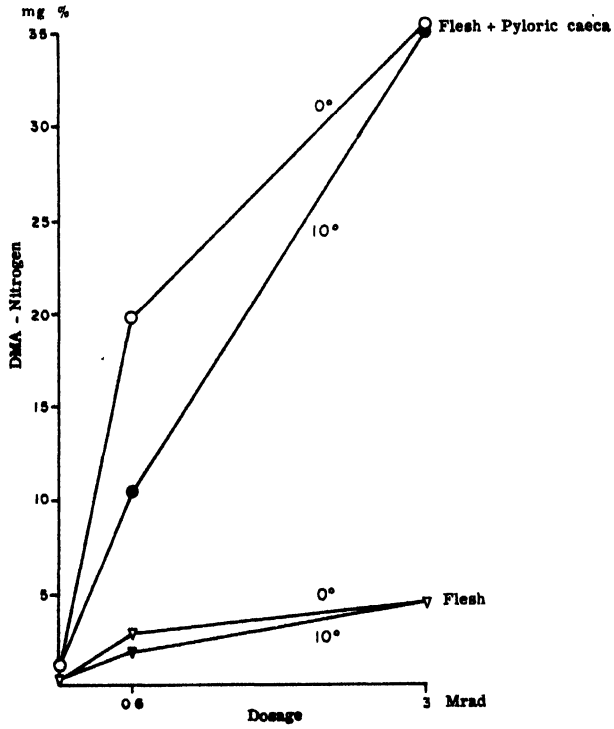


Fig 4. DMA formation in the irradiated mixture of cod flesh and cod pyloric caeca

increase of DMA was noticed in the same mixture without irradiation but stored for the same length of time as the irradiated samples (fig 4 and table 4). Temperature variation during the irradiation showed little effect.

TABLE 4. CHANGES IN THE AMOUNT OF DMA IN THE NON-IRRADIATED MIXTURE OF FLESH AND PYLORIC CAECA OF TWO GADOID SPECIES IN 23 H IN TERMS OF PERCENTAGE MILLIGRAMS OF NITROGEN

Storage	*Cod (A)*		*Alaska pollack*	
(h)	*0°C*	*10°C*	*0°C*	*10°C*
0	1.0	0.8	0.3	0.3
23	1.8	2.6	0.4	0.8

As shown in table 5, irradiation of the pyloric caeca alone did not promote DMA formation when it was added to non-irradiated flesh of cod. Another experiment was conducted to see whether any alteration in the muscle tissue or TMAO configuration by irradiation would be needed to accelerate DMA formation. No difference was observed, however, of DMA formation in the irradiated cod flesh, whether or not pyloric caeca had received irradiation before the mixture was made (table 6). These findings indicate that irradiation of the flesh and pyloric caeca at the same time is essential to enhance DMA

TABLE 5. INCREMENT IN THE AMOUNT OF DMA IN THE MIXTURES COMPOSED OF NON-IRRADIATED COD FLESH AND IRRADIATED COD PYLORIC CAECA WITHOUT FURTHER IRRADIATION IN PERCENTAGE MILLIGRAMS OF NITROGEN

	Condition of storage		
	0°C, 23 h	*10°C, 23 h*	*25°C, 5 h*
Control (non-irradiated flesh plus non-irradiated pyloric caeca)	0.15	0.16	0.07
Treated [non-irradiated flesh plus irradiated (3 Mrad) pyloric caeca]	0.10	0.17	0.09

TABLE 6. CHANGE IN THE AMOUNT OF DMA IN THE MIXTURES OF IRRADIATED COD FLESH AND IRRADIATED OR NON-IRRADIATED COD PYLORIC CAECA IN PERCENTAGE MILLIGRAMS OF NITROGEN

Incubation	*Irradiated cod flesh*	*Irradiated cod flesh plus non-irradiated pyloric caeca*	*Irradiated cod flesh plus irradiated pyloric caeca*	*Irradiated mixture of cod flesh and pyloric caeca*
0 h	5.5	6.4	6.3	45.5
10 h (10°C)		6.5	6.5	
10 h (0°C)		6.5	6.6	

formation. It is quite clear in fig 5 that the activity can be completely lost when pyloric caeca has been heated and this may suggest that the enhancement is dependent on a certain enzyme, although the irradiation plays an important role in the reaction.

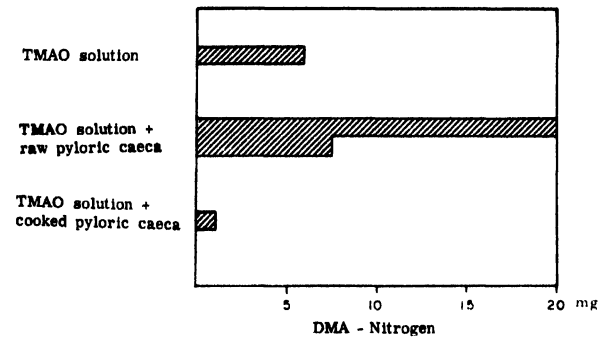


Fig 5. Amount of DMA produced after irradiation of the mixture of TMAO solution and raw or cooked homogenate of pyloric caeca of cod at 3.0 Mrad

DISCUSSION

Production of monomethylamine and ethylamine has been reported as a result of gamma-irradiation of beef (Burks *et al.*, 1959) and these amines have also been described in the irradiation of amino acids, where glycine forms monomethylamine while alanine produces ethylamine (Sharpless, 1955). However, no information is available about radiochemical formation of TMA or DMA. This may be due to the fact that formation of TMA or DMA will hardly occur when amino acids or protein are subjected to irradiation. In the present experiment, TMA or DMA was not found in the irradiated flesh of carp, which was regarded deficient in TMAO owing to habitation in freshwater. TMA and DMA which appear in the irradiated flesh of fish like cod most probably are derived from TMAO.

TMA formation from TMAO may occur by reduction of TMAO caused by the action of hydrogen radicals generated during the ionizing radiation of the water in the tissues of fish. It is not certain, however, whether DMA or FA can be formed by dissociation of TMAO under irradiation, or by demethylation of TMA produced during the course of the TMAO reduction mentioned above.

A possible formation of FA has been shown by the irradiation of certain amino acids (Maxwell, 1954) and, in addition, many types of carbonyl compounds can be produced from lipids and fatty acids (Mitchell, 1957). In

this respect, various substances contained in fish flesh other than TMAO could be precursors of FA. Appreciable amounts of FA observed in the irradiated carp meat is a good example. In the case of cod flesh, however, TMAO may be the major substance to yield FA, since FA is always formed in equivalent amounts to DMA. The amount of FA produced from TMAO should be balanced with that of DMA; however, the quantity determined usually shows a smaller yield. One of the reasons for a lower yield of FA in the flesh may be due to the difficulty of FA extraction from the tissues to which FA is strongly bound. A smaller yield of FA in the irradiated TMAO solution than theoretical values may also be attributed to further oxidation of FA into formic acid (Hart and Platzman, 1961). As far as the quantity of FA produced in the irradiated cod flesh is concerned, there is no question of toxicity, since the level of FA is lower than 10 mg per cent. If cod flesh, however, is contaminated by its viscera, particularly by pyloric caeca, FA will reach a level of 100 mg per cent according to the circumstances.

It is noteworthy that DMA formation by irradiation differs with species of fish as well as individuals of the same species. In one example of Alaska pollack, the amount of DMA was much larger than that from a pure TMAO solution, being almost double in quantity at the same dosage of 3.4 Mrad. This may not agree with the general concept that the quantity of decomposed products from certain substances by irradiation is believed smaller in a biological system than in a pure form.

A major factor involved in enhancement is evidently enzymatic, because the acceleration of DMA formation never happens when the pyloric caeca has been heat processed. It is also observed that a simple irradiation of pyloric caeca does not activate the reaction. Further, no acceleration can occur where the irradiation of the flesh and pyloric caeca is performed separately. Co-existence of both flesh and pyloric caeca at the same site of reaction is a prerequisite during irradiation. As it has been reported by the writer (Amano and Yamada, 1964) gadoid fish are gifted with a specific enzyme to split TMAO into DMA and FA. The enhancement of DMA formation by irradiation may also be connected to the same principle. But the rate of reaction may be dependent on the active role of free radicals generated from radiation decomposition of water molecules in the tissues.

SUMMARY

Under gamma-irradiation at dosages of 0.6 to 5.6 Mrad, formations of TMA, DMA, ammonia and FA were demonstrated in fish flesh containing TMAO by nature. These compounds were also detected in the irradiated TMAO solution with the exception of ammonia.

In the irradiation of marine fish, it may be concluded that the precursor of TMA and DMA could be TMAO, but ammonia may be derived from some nitrogenous compounds other than TMAO. In ordinary sea fish, various substances in their tissues could be precursors of FA during irradiation, however, TMAO is the most probable one for FA formation in the gadoid species of fish.

The amount of DMA formed by irradiation was found variable with species of fish as well as in individuals of the same species. Individual difference was particularly noted in the gadoid group. The difference in the activity of specific enzymes to split TMAO into DMA and FA was noted.

Enhancement in DMA formation of irradiated cod or Alaska pollack may be explained by a coupled reaction of the specific enzyme of these species, and free radicals generated during the irradiation.

References

AMANO, K and YAMADA, K *Bull. Jap. Soc. scient. Fish.*, **30**, 1964 639.

BURKS, R E, *et al. J. agric. Fd Chem.*, **7**, 778. 1959

BYSTEDT, J *J. Sci. Fd Agric.*, **10**, 301. 1959

DYER, W J and MOUNSKY, Y A *J. Fish. Res. Bd Can.*, **6**, 359. 1945

HART, E J and PLATZMAN, R L *Mechanisms in Radiobiology*, 1961 Academic Press, New York, **1**, 234.

HATTORI, Y and HASEBE, S *J. pharm. Soc. Japan*, **57**, 928. 1937

HAYASHI, M and UNEMOTO, T *J. Jap. Chem.*, Extra Issue, 1961 **47**, 61.

MAXWELL, C R *Radiat. Res.*, **1**, 530. 1954

MITCHELL, J H, JR *Radiation Preservation of Food.* U.S. 1957 Army Research and Development Series, **1**, 119.

NASH, T *Biochem. J.*, **55**, 416. 1953

SHARPLESS, N E *Radiat. Res.* **2**, 135. 1955

SOUDAN, FRANCE *Revue Trav. Inst. (scient. tech.) Pêche marit.*, 1959 **23**, 203.

Complementary Effect of Food Preservative and Gamma Radiation Treatment of Whale and Horse Mackerel Flesh

by T. Tomiyama, S. S. Jeng, E. Shiraishi, M. Hamada and Y. Yamada

Complementary effect of food preservative and gamma radiation treatment of whale and horse mackerel flesh

The effect of chemical preservatives (furylfuramide and chlortetracycline) in reducing the irradiation dosage required to extend the shelf life of whale and horse mackerel (*Trachurus japonicus*) flesh has been investigated. The authors report that while these preservatives are completely inactivated in aqueous solution by 0.1 Mrad they are protected to some extent in the presence of the fish flesh. The combined effect of the chemical preservative treatment and irradiation appears to be synergetic rather than additive and a greater preservative effect is obtained if the chemical treatment precedes the irradiation.

The investigations also indicated that 0.2 Mrad irradiation can control the *B. subtilis* spores remaining in inoculated and tylosin-treated whale meat after a mild cooking.

Effet complémentaire des agents de conservation et de l'irradiation gamma sur la chair de baleine et de chinchard

Les auteurs ont étudié le rôle que peuvent jouer des agents de conservation chimiques (furfurylamide et chlortétracycline) dans la réduction de la dose d'irradiation nécessaire permettant d'accroître la durée de conservation de la chair de baleine et de chinchard (*Trachurus japonicus*). Ils signalent que les agents conservateurs totalement inactivés en solution aqueuse par 0,1 Mrad, sont dans une certaine mesure protégés dans la chair des animaux aquatiques. L'effet combiné du traitement aux agents chimiques et par irradiation paraît être synergique plutôt qu'additif, et la conservabilité est supérieure si le traitement chimique précède l'irradiation.

Les expériences ont également révélé qu'une irradiation de 0,2 Mrad peut détruire les spores de *B. subtilis* demeurant dans de la chair de baleine inoculée et traitée à la tylosine après une légère cuisson.

El efecto complementario de los preservativos químicos de alimentos y del tratamiento con radiaciones gama sobre la carne de ballena y de jurel

Se ha investigado el efecto de sustancias preservadoras químicas (furilfuramida y clorotetraciclina) para reducir la dosis de irradiación necesaria para ampliar el periodo de conservación de la carne de ballena y de jurel (*Trachurus japonicus*). Los autores comunican que aunque estas sustancias preservadoras quedan completamente inactivadas en solución acuosa por irradiación de 0,1 Mrad, se hallan en cierta medida protegidos en presencia de la carne de pescado. El efecto combinado del tratamiento con sustancias químicas de conservación y con irradiaciones parece ser más sinérgico que aditivo, obteniéndose una mejor conservación si a la irradiación precede el tratamiento químico.

Las investigaciones indicaron igualmente que la irradiación de 0,2 Mrad puede destruir las esporas de *B. subtilis* que quedan en la carne de ballena inoculada y tratada con tilosina después de una moderada cocción.

ONE of the disadvantages of applying ionizing radiation to the preservation of fresh or cooked muscle tissues is that discolouration and off-flavour result from radiation with higher doses than 0.5 Mrad (Miyauchi, 1958). So it is an important task to lower the effective dose to 0.1–0.2 Mrad by combining it with some other means of preservation.

The present study was made to find whether the complementary effect of food preservatives can actually help lower the effective dose of radiation.

METHOD

Materials

Frozen whale meat and horse-mackerel (*Trachurus japonicus*) were procured from the market. The frozen meat was thawed at room temperature, ground and diluted 1 : 1 with an aqueous solution of 5 ppm of butylated hydroxyanisole (BHA). Horse-mackerel flesh was excised from the round fish, ground and diluted as above. Food preservatives used were furylfuramide [2-(2-furyl)-3-(5-nitro-2-furyl) acrylic acid amide] (FF), chlortetracycline (CTC) and tylosin (TL). Each was supplied from the respective manufacturer.

Irradiation treatment

About 10-g aliquots of the diluted muscle samples with or without food preservatives were placed in sterile test tubes (2 × 11 cm), stoppered with cotton plugs, and then irradiated by a ^{60}Co source of 1.5 kci at varying distances from the source depending on the required dose of radiation. The time of exposure ranged from 2 to 5 h and the temperature was about 10°C (50°F). When any preservative was added after this treatment, an aliquot volume of the sterile preservative solution was added in a sterile chamber.

Experimental groups

Group 1—Control A, no irradiation and no preservatives. Group 2—Control B, no irradiation, but with preservatives. Group 3—Control C, no preservatives, but irradiated with 0.05 Mrad (R–1), 0.1 Mrad (R–2), 0.5 Mrad (R–3) and 1 Mrad (R–4) respectively. Group 4—FFB and CTB; each food preservative was added before the irradiation of 0.1 Mrad dose. Group 5—FFA and CTA; each preservative was added after the irradiation of 0.1 Mrad dose. All these series of samples were kept at 11±1°C (50 to 53.5°F). At intervals each test

tube sample from the various groups was tested for organoleptic score and microbial count.

Method of assay

FF was bioassayed by using *B. natto* on a DMF-acetone extract, CTC by using *B. cereus* on a citrate-acetone extract, and TL by using *S. lutea* on an aqueous extract of sample. The microbial count was determined by the routine plate count method.

RESULTS

Inactivation of food preservatives by gamma irradiation

Figure 1 shows that FF (20 ppm), CTC (5 ppm) and TL (40 ppm) in aqueous solutions of pH 6.5 were all completely inactivated with radiation doses greater than 0.1 Mrad. It is of interest that a 5 ppm level of BHA

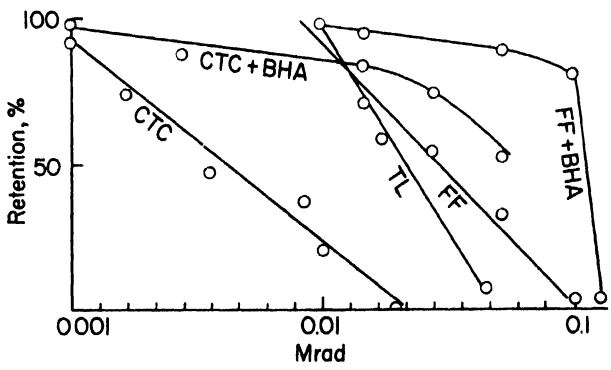


Fig 1. Inactivation of FF and CTC in buffer solution (pH 6.5) with or without BHA

was able to prevent FF and CTC from the inactivation, probably by capturing free radicals formed. It was also found that the muscle tissues employed could markedly protect these preservatives against the radiation inactivation (fig 2).

These data suggest the use of these preservatives for enhancing the efficacy of radiation at about 0.1 Mrad in keeping the freshness of muscle tissues.

Complementary effect of radiation and food preservatives in keeping quality of fresh muscle

Data on the increase in the microbial count during the storage of the whale meat are illustrated in fig 3.

The organoleptic scores are presented in table 1.

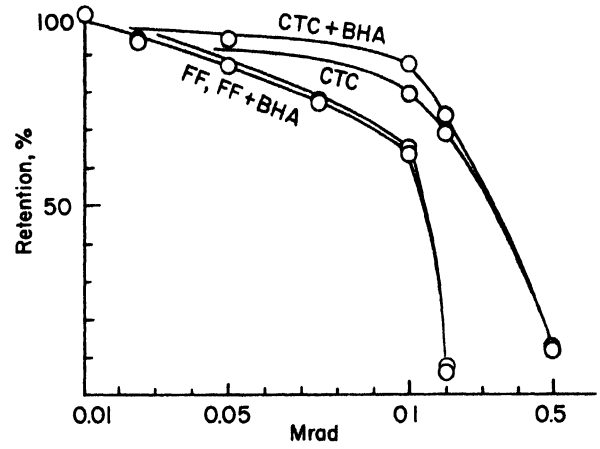


Fig 2. Inactivation of FF and CTC in whale meat with or without BHA

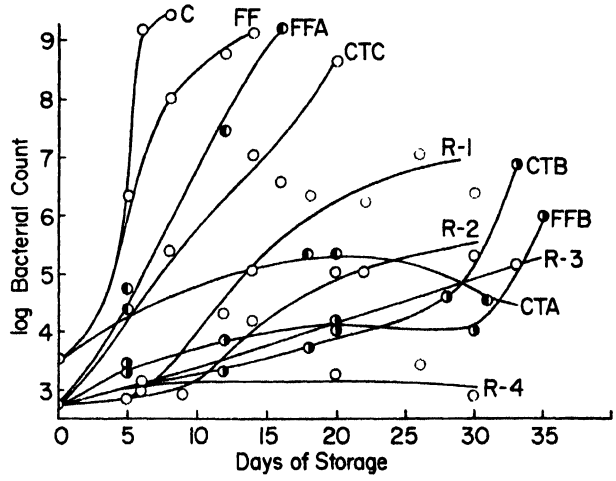


Fig 3. Increase in bacterial count of whale meat submitted to various treatments and stored at 11°C

Although there are appreciable fluctuations in these scores during storage, the data as a whole clearly indicates that the irradiation treatment (0.1 Mrad) in the presence of FF (20 ppm) and CTC (10 ppm) was far more effective in the inhibition of microbial growth as compared with either the irradiation or the chemicals alone. The effect seems to be synergetic rather than additive. It is to be noted that the effectiveness of 0.1 Mrad in combination with the preservatives was nearly equal to that of 0.5 Mrad alone.

TABLE 1. ORGANOLEPTIC SCORES FOR VARIOUS GROUPS USING WHALE MEAT

Experimental group	*Days stored*																			
	0	3	5	6	8	12	13	14	16	17	18	20	21	22	23	24	26	28	30	31
C	1	1	2	5	5	5	5	5												
R-1	1	1	2	3		4	5	4	5	5	5	5								
R-2	1	1	1	2	1	4	4	5	5	5	5	5								
R-3	1	1	1	1		1		1			1	1			1		1			
R-4	1	1	1	1		1					1		1						1	
FF			1		1	4	5	5	4		5									
FFB			1		1			1			3	5		3	3	3	3		5	5
FFA			1		1	4	4	5	4		5									
CTC			1		1							5								
CTB			1		1			1			1	1			1	1	4	5		
CTA			1		1	1		1			1	3		4	5	5			5	5

1, No change; 2, fishy odour; 3, slight off-odour; 4, slighly putrid; 5, putrid.

It is of interest to note that when any of the preservatives was added before irradiation, the complementary effect was greater than when added after irradiation. The difference in the effectiveness was greater in the FF group.

As shown in fig 4, a sharp decrease was noted in FF residue in the whale meat after a three-day storage. The senior author has reported that this decrease was caused by an enzymatic action. In case of CTC, the complementary effect was remarkable whether CTC was added before or after the irradiation, and this seems to relate to a comparatively high retention of CTC in either case (fig 5).

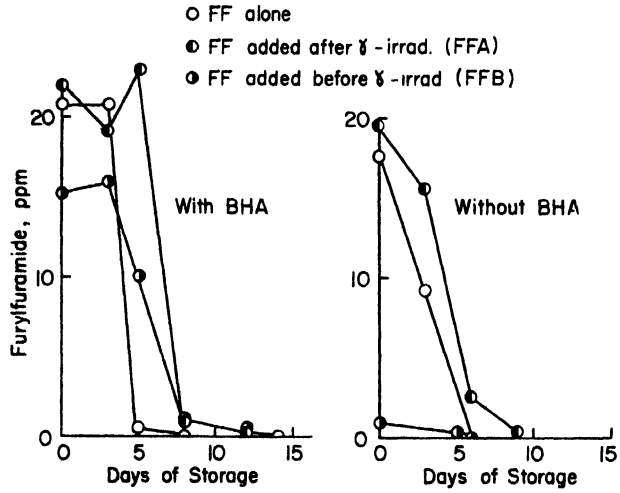


Fig 4. Decrease in FF-residue in whale meat during storage at 11°C

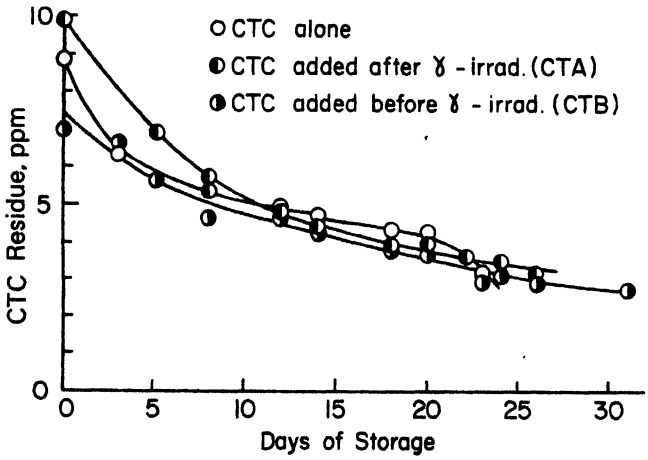


Fig 5. Decrease in CTC residue in whale meat during storage at 11°C

A similar experiment was carried out with horse-mackerel flesh. The organoleptic scores are given in table 2.

As will be seen from fig 6, the microbial growth patterns in various groups were comparable to those for the whale meat except for an earlier incipient spoilage, lower effectiveness at 0.1 Mrad and higher effectiveness of the FF group. The group with FF added after irradiation were slightly inferior in freshness to the group with FF added before the treatment. This can be accounted for by a higher retention of FF in the fish flesh during storage (fig 7). The retention of CTC is shown in fig 8.

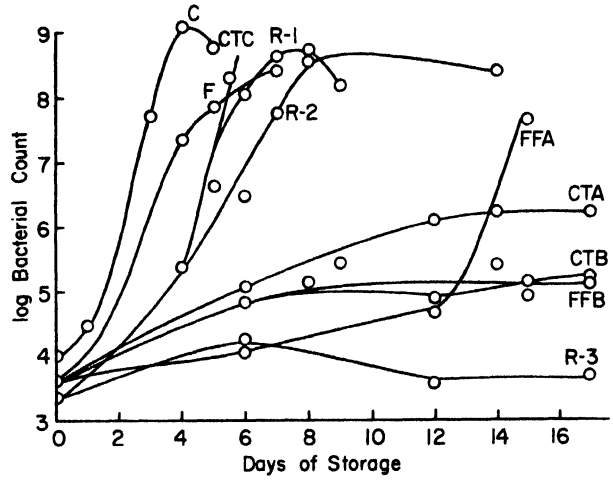


Fig 6. Increase in bacterial count of horse-mackerel flesh submitted to various treatments and stored at 11°C

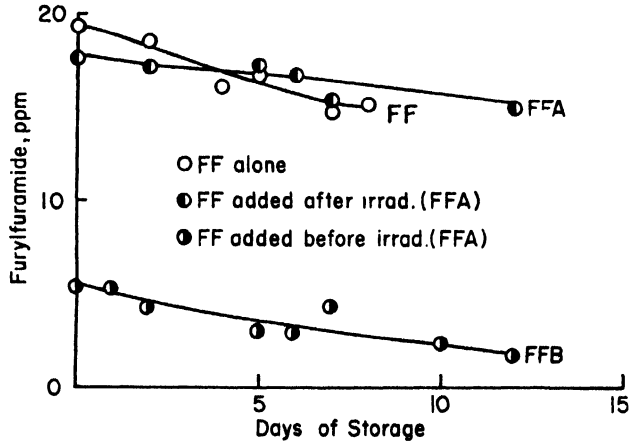


Fig 7. Decrease in FF-residue in horse-mackerel flesh during storage at 11°C

TABLE 2. ORGANOLEPTIC SCORES FOR VARIOUS GROUPS USING FISH FLESH

Experimental group	Days stored																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	19
C	1	1	2	4	5												
R-1		1			1	1	4	4	5								
R-2		1			1	1	1	1	1	2		3	3	4	4		
R-3		1			1	1	1		1	1		1				1	
FF		1		1	5	5	5	5	5								
FFB		1		1	1	1	1	1	1	1	1	1	1	1	1	3	3
FFA		1		1	1	1	1	1	1	1	1	1	1	2	3		
CTC		1		1	4	4	5	5	5								
CTB		1		1	1	1	1	1	1	1	1	1	1	1	1	1	
CTA		1		1	1	1	1	1	1	1	1	1	1	1		3	

Figures showing the degree of spoilage are the same as those given in Table 1.

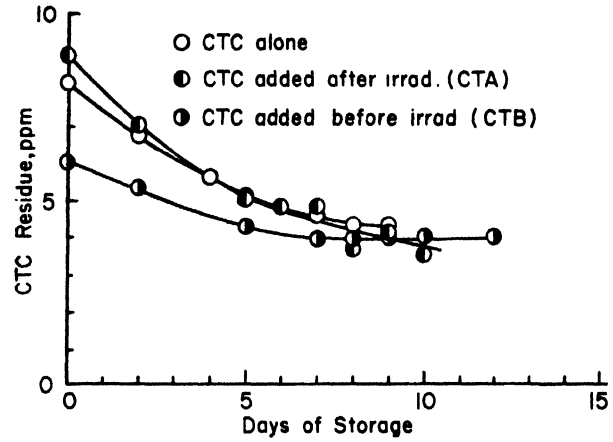


Fig 8. Decrease in CTC residue in horse-mackerel flesh during storage at 11°C

These data indicate that a combination of preservatives and irradiation treatment have a synergetic effect on the keeping quality of fish flesh.

Complementary effect of irradiation treatment and tylosin in keeping quality of cooked whale meat

Figure 9 indicates a marked complementary effect of TL when *B. subtilis*-inoculated whale meat with or without TL was subjected to a 30-min heating at 85°C (185°F) and irradiated with 0.2 Mrad. The results suggest that *Cl. botulinum* spores could be killed by a complementary treatment of TL and irradiation of 0.2 Mrad dose.

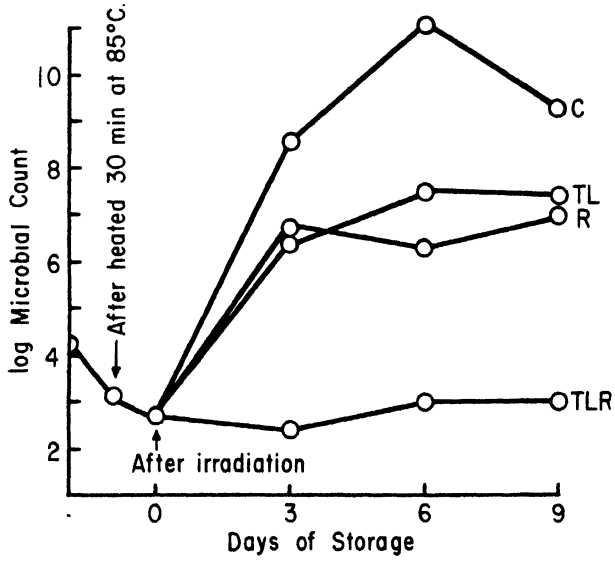


Fig 9. Change in viable B. subtilis *spore with TL and/or irradiation (0.2 Mrads)*

DISCUSSION

Three kinds of food preservatives were tested in the present study. Tetracycline antibiotics, among others, are allowed for fish preservation in several countries. Based on safety data, the use of furylfuramide has recently been allowed in Japan for the preservation of fish sausage. Tylosin, a kind of antibiotic, has not yet been approved in any country, but safety data seems to suggest its future approval.

It is already known that the preservative effect of ionizing radiation can be increased by the presence of CTC and OTC (Niven and Chesbro, 1956–57; Shewan, 1959; Lerke, Farber and Huber, 1961). No report, however, has been made on the extent of the radiation inactivation of these antibiotics in tissues. Therefore, it is not known whether the preservatives should be added before or after irradiation treatment. In this respect the present study made two approaches. Studies were made, first, on the stability of the preservatives to the irradiation in aqueous solution and in muscle tissues, and secondly, on the complementary effect of the food preservatives and irradiation treatment on keeping quality of fresh and cooked muscles.

It has shown that a dose level of 0.1 Mrad was not very detrimental to the preservatives in tissues, although they are totally inactivated in aqueous solution. The marked effectiveness of BHA (5 ppm) in protecting them from inactivation suggests a need to study on the effect of increasing its level in the meat. It should be mentioned that FF-containing meat which was irradiated in the presence of BHA (5 ppm) possesses a shelf life of 17 days, whereas the same group without BHA had only eight days' shelf life.

From the practical standpoint, it is of interest that a better effect can always be obtained when the preservatives are added prior to the irradiation treatment. This suggests that the presence of the preservatives affects the spoilage microbes in some way and makes them more susceptible to the radiation treatment.

Due to scarceness of thermophilic bacteria in ordinary meat, it was difficult to demonstrate the complementary effect of tylosin and irradiation treatment on cooked meat. However, when *B. subtilis*-inoculated meat with or without TL was subjected to the irradiation of a 0.2 Mrad dose following a mild cooking, it was shown that a combination of TL and irradiation treatment had a very marked synergetic effect. It appears, therefore, that this combination treatment may provide an effective method for eradicating the botulinum spores in the canned foods.

SUMMARY

(1) CTC, FF and TL in aqueous solution of pH 6.5 are completely inactivated at a 0.1 Mrad dose, but in tissues they are protected to some extent against the irradiation inactivation.

(2) A higher complementary action of the preservatives and the irradiation treatment can be obtained by adding the preservatives before the irradiation.

(3) When combined with irradiation at 0.2 Mrad, TL can completely control *B. subtilis* spores which remain in the meat after a mild cooking.

References

LERKE, P A, FARBER, L and HUBER, W 1961 Preservation of fish and shell fish by relatively low doses of beta radiation and antibiotics. *Fd Technol., Champaign*, **15**, 145–152.

MIYAUCHI, D T 1958 *Comml Fish. Rev.*, **20**(2), 16–17.

NIVEN, C F, JR and CHESBRO, W R 1956–7 Complementary action of antibiotics and irradiation in the preservation of fresh meats. *Antibiotics A.*, 855–859.

SHEWAN, J M 1959 The present status of radiation preservation of food products—fish. *Int. J. appl. Radiat. Isotopes*, 143–146.

DISCUSSION

Charm (U.S.A.): I would like to suggest that the correlation between number of micro-organisms and organoleptic qualities would be more reasonable if the time micro-organisms act is considered rather than just their number. In other words a small number of micro-organisms acting over a long period of time will degrade quality to the same degree as a large number acting over a short period.

Hansen (Denmark): Spinelli's paper contains a list of very useful and relevant indices to follow quality changes during chilled storage of irradiated fish. It is limited in scope, however, to lean fish species. Irradiation of fatty fish is possible and feasible provided special precautions such as effective vacuum packing and antioxidant treatment, are taken prior to packing and irradiation. If irradiation of fatty fish is considered, some more indices of quality are needed as estimation of rancidity and other oxidative changes.

Tomiyama (Japan): To answer Hansen's comment about the antioxidant treatment of oily fish before irradiation, I would like to mention our experiment in which we showed the addition of very low level of BHA to be effective in inhibiting the rancidity of irradiated mackerel flesh. Surprisingly enough the irradiation effect was not lowered by this addition of BHA.

Liston (U.S.A.): I wonder if Spinelli would comment on the bound-ribose technique for estimating hypoxanthine.

Spinelli (U.S.A.): Bound ribose is determined by passing a perchloric acid extract of the fish tissue made alkaline with NH_4OH to pH 10.5 over a Dowex 1 8XCL column. Under these conditions, bound ribose in the form of either nucleotides or inosine is absorbed. It can then be eluted with 4N HCl and determined with orcinol.

Tomiyama (Japan): With regard to the rapid determination of bound ribose, we have found that the simplest way is to use activated charcoal to pick up the riboside or nucleotide which can then be determined after acid hydrolysis.

Hansen (Denmark): Figure 7 in Spinelli's paper shows the gradual decrease of eating quality of irradiated fish stored at 0.5°C. Very similar gradual quality losses were found in our Danish storage experiments with irradiated trout in wet ice, i.e. at 0°C. A rise of only a few degrees of the storage temperature will lead to much faster increases of hypoxanthine and faster losses of eating quality rendering the whole process unfeasible. It is thus essential to maintain the storage temperature of radurized fish very close to 0°C. This temperature control also removes the danger of botulinium toxin developing while the fish is airtight packed.

Michon (France): Je suis étonné de constater, dans les documents présentés par M. Sierra Serrano une baisse de l'indice des bases azotées volatiles immédiatement après l'irradiation.

M. Sierra Serrano, ou quelqu'un de l'assemblée peut-il m'en fournir l'explication?

Sierra Serrano (Spain): En contestación a la pregunta de porqué el nitrógeno básico volátil total disminuye con la irradiación, se debe decir que la razón es sencilla y reside en la estrecha correlación de la destrucción de bacterias y la producción del citado nitrógeno básico volátil total.

Sidhu (Australia): It was mentioned earlier in the Conference, and has been our experience also, that production of ammonia continues in shark fillets even under frozen storage. In view of the differential destruction, by irradiation, of bacteria producing volatile bases in fish, I wonder if one could expect similar effects on bacteria producing ammonia in shark fillets. I would like to know if any work has been done on the irradiation of elasmo-branch fish.

Slavin (U.S.A.): With regard to the point that quality of irradiated products may appear different to the consumer, it appears that dose influences quality. We know that the microbial flora changes with an increase in dose and that most changes occur at levels higher than 200,000 rads. These microbial changes and chemical changes indicate the product is different from the fresh. Also, we know at the higher levels there is a long period where it is difficult to recognize spoilage because it does not appear as pronounced as in fresh fish.

Subba Rao (FAO): The problem of infection of tropical fish by parasites is a serious one. People in northern parts of South-east Asia and in South China habitually consume raw freshwater fish, many species of which are infected by parasites such as platyhelminths or flukes as they are better known. The fish are consumed raw either as fillets sprinkled with lemon juice or fermented for a short period after light salting. Consumption of such fish in a raw state results in liver fluke infection and has led to serious deterioration in the health standards of the people in this area. The main species concerned are the *Clonarchis* and *Ophistovchis*. The primary host is the *Bithynia* snails and after passing through the stages of redia and cercaria, the flukes pierce the fish skin and exist there in an encapsulated form in the muscle. One of the species, *Olonorchis*, is not easily destroyed by cooking. It is desirable to investigate the possibility of applying gamma ray irradiation to destroy these flukes before the fish are sold to the consumers.

Szabo (FAO): Possibilités pour l'application des irradiations contre l'infestation biologique des poissons séchés. La Mali, pays sans côte, pêche dans les eaux intérieures du bassin du Niger. Capture annuelle: 100.000 t de poissons frais. Un tiers est consommé à l'état frais et deux tiers sont transformés en poisson séché et fumé. Exportations vers le Ghana, la Côte d'Ivoire, la Haute Volta. Les poissons frais séchés à l'air sont attaqués par *Dermestes maculatus* et *Necrobia rufipes*, qui produisent des pertes atteignant 4.000 à 5.000 t/an.

Des études et rapports ont été faits par l'Association pour le Développement des Applications Industrielles des Radiations (ADAIR) et l'Institut de Recherches Agronomiques Tropicales (IRAT) en liaison avec la Compagnie Générale de Télégraphie Sans Fil (CSF)-France. Les résultats sont positifs: il s'agit d'irradier les mâles et de les stériliser.

Les quantités à traiter: 6.000 t de poisson séché. Les quantités journalières à traiter varient avec les fluctuations météorologiques et le niveau d'eau; les conditions de transport sont troublées par manque de motorisation des moyens de transport.

Implantation de stations: notamment dans la ville de Mopti sur la boucle du Niger où se déroule toute l'activité commerciale, principalement l'exportation.

Amano (Japan): In connection with Liston's paper, bacterial number indicates comparatively rapid increase, say 10^4 within 10 or 20 days. I presume this might be caused by air which did penetrate through a rather permeable polymylar pouch. In my experience you can prolong the shelf life by

replacing this package with aluminium foil pouch. In addition, I would be pleased if anyone can tell me what is the most suitable packaging material that can be used for fish under irradiation.

Liston (U.S.A.): I'm sure you're correct. These packs were not completely airtight anaerobic packs. There is enough residual oxygen in any case in the pack to provide for growth. I would comment that we consider this a desirable feature because one aspect of the low dose and double dose irradiation which we're driving towards, is the re-establishment of a normal spoilage —a long delayed normal spoilage—which might help to resolve any possible problem with botulism. But you're perfectly correct in your interpretation.

Holston (U.S.A.): In most countries, radiation would be considered a food additive and, as such, approval, when given, would be for the "minimum efficacious dose". This dose and the optimal dose might not, and most probably would not, coincide. Thus, we must base our work on (1) a clear definition of the shelf life extension needed and which can be demonstrated to be beneficial to both the seller and the consumer and (2) on bacterial survival/dose rate curves. Then, the minimum efficacious dose, i.e. that necessary to give the desired and justified shelf life extension, can be readily determined and tested under commercial conditions. Our informal definition of the minimum efficacious dose for haddock and cod is that dose which consistently results in a 99 per cent bacterial reduction and which affords an extension of shelf life of from 12 to 14 days. We damage our case by continuing to talk of 30 or 40 days extension, when such is neither legally defensible nor needed by industry. This is especially true when we consider that other quality attributes are degraded long before the 30- or 40-day interval resulting in an unspoiled, but unappetizing product.

Status of Legislation on Irradiated Food

by H. E. Goresline

Status of legislation on irradiated food

For some 14 years there has been intensive research on the feasibility and practicability of the use of ionizing radiation as a food processing method. This research has shown that there is promise for such processing with certain food commodities and that the method can be applied in competition with the other conventional methods. These facts have made it evident that commercial irradiated food products are going to appear on the market and eventually will become articles of international trade.

Before such use can be made of any process there must be proof that it is safe, the processed food products wholesome and nutritious and that they have been processed under the proper conditions of quality and sanitary and public health control. The feeling that control is necessary to assure such conditions has given rise to the promulgation by individual countries of legislation and regulations pertaining to the control of each step in the procedure towards the offering for sale of irradiated items of food.

This paper is a report of a survey of world legislation on food irradiation as it now stands. Examples are given of the type and coverage of various control measures and the procedures that are followed in arriving at the approval of individual items for human consumption. Also presented are some of the testing procedures used to establish the wholesomeness of irradiated food, including animal feeding and microbiological studies. It is against this background that the irradiation processing regulations for fish and seafoods are discussed.

État de la législation relative aux aliments irradies

Il y a quelque 14 ans que l'on procède à des recherches poussées sur la possibilité d'employer les radiations ionisantes dans l'industrie alimentaire. Les travaux ont révélé que cette méthode est prometteuse pour le traitement de certains aliments, et peut concurrencer les méthodes classiques. Aussi est-il certain que les produits alimentaires irradiés vont faire leur apparition sur le marché, et par la suite dans le commerce international.

Avant qu'un procédé, quel qu'il soit, parvienne à ce degré d'utilisation, il doit être établi qu'il ne présente pas de danger, donne des produits alimentaires sains et nutritifs, et satisfait aux normes voulues du point de vue de la qualité, de l'hygiène et de la santé publique. Le sentiment qu'une certaine surveillance est nécessaire pour assurer que ces conditions sont réunies a incité divers pays à promulguer des textes législatifs et des règlements concernant le contrôle de chaque phase du processus qui aboutit à la mise en vente de produits alimentaires irradiés.

La présente communication passe en revue la situation actuelle de la législation mondiale relative aux aliments irradiés. Elle donne des exemples du type et du champ d'application de diverses mesures de contrôle ainsi que des modalités d'approbation des divers articles destinés à la consommation humaine. Elle expose également certaines des épreuves utilisées pour établir l'innocuité des aliments irradiés, y compris les essais sur animaux et les études microbiologiques. C'est dans ce cadre que sont examinés les règlements intéressant le traitement par irradiation des poissons et autres produits de la mer.

Situación actual de la legislación sobre alimentos irradiados

Durante catorce años se han venido haciendo intensas investigaciones sobre la posibilidad y conveniencia de utilizar las radiaciones ionizantes como método de elaboración de alimentos: las investigaciones han mostrado que este método podría competir con los demás métodos tradicionales y que para algunos productos alimentarios daría buenos resultados. Esto revela que los productos alimentarios comerciales irradiados están a punto de aparecer en el mercado, y que acabarán convirtiéndose en artículos del comercio internacional.

Antes de que pueda utilizarse cualquiera de estos procedimientos, deben tenerse pruebas de su seguridad, de que los productos alimentarios así elaborados son sanos y nutritivos, de que su elaboración ha estado sujeta a las normas públicas, higiénicas y sanitarias, y de que el producto elaborado reúne las debidas condiciones de calidad. Para asegurar el cumplimiento de tales condiciones se ha juzgado que era necesario un control, y ello ha dado lugar a que diversos países promulguen normas y reglamentos para cada fase del proceso de elaboración de los artículos alimenticios irradiados que se ponen en venta.

Este trabajo informa sobre la actual legislación mundial relativa a la irradiación de alimentos. Se dan ejemplos del tipo y alcance de las diversas medidas de control y de los trámites necesarios para conseguir que los diversos artículos puedan destinarse al consumo humano. Se exponen también algunos de los procedimientos de comprobación utilizados para determinar la salubridad de los alimentos irradiados, entre ellos los estudios microbiológicos y de la alimentación animal. Teniendo presente lo anterior, se discuten las normas sobre los procedimientos de irradiación del pescado y otros alimentos de origen marino.

IT has been said that the use of ionizing radiation in the preservation of food is the first new and novel processing method developed in this century. Its development came at a time when there was growing concern about the biological burden caused by the increased use of chemicals in food industry and from the use of insecticides in the fields. Accordingly, it has been subjected to a scrutiny as to the safety of its use beyond that of any food processing method that has been used. Although one of the claims put forward for the use of ionizing radiation is that no chemical residues result from its use, in most countries the regulation of the use of this method has been under the laws pertaining to food additives.

We live in an era of regulations concerning almost every activity of human endeavour and it is natural, therefore, to expect that a new food processing method would not only be scrutinized before being given approval but also its use regulated in food preservation. It has been necessary, therefore, to promulgate special legislation to cover the manufacture, distribution and utilization of ionizing radiation and the resulting products.

From the very beginning of the research on the feasibility of the use of this new processing method there has been a realization that if proven successful in the preservation of food there would naturally result an international trade in such food items. It was realized also that there would be need for legislation that would facilitate the movement of such items in international commerce and that to accomplish this there should be a similarity of legislation that would encourage and not impede such trade. It was to encourage such action and to provide guidance in the formulation of legislation in this field that the Food and Agriculture Organization of

the United Nations (FAO), the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) jointly convened an International Panel of Experts in Rome, 21st to 28th April 1964, to discuss this matter. The report of this meeting was entitled "The Technical Basis for Legislation on Irradiated Food". It set forth the basic concepts that should be considered in formulating legislation, suggestions on the testing procedures to be employed in determining wholesomeness, freedom from toxicity or microbiological hazard and nutritional adequacy of irradiated food and feeds. It did not set forth suggested legislation. This report was distributed to all of the Member Governments of the three organizations for voluntary use in preparing any legislation that they considered necessary to control the use of this new process. It was hoped that this report would serve to give enough similarity of legislation on a world basis to ease possible trade barriers.

At this point it would be well to pause to point out an unusual anomaly with regard to questions on the legislation on irradiated food. It is repeatedly asked, "Why is irradiated food forbidden in most countries?" Such a question supposedly arises from lack of information or understanding of legal procedures or the fact that it has been a long time since a new food processing method has had regulations for it discussed in the newspapers. It is necessary to point out that most legal actions of this kind proceed by making an action illegal and then upon proof of safety give exception or clearance under the law. In most countries it is forbidden to add chemical substances to food except when it has been proven that there is no harmful effect, and when this has been complied with clearance for the use of the material is given. Irradiated food is treated in the same way as other types of food. In countries where there are regulations controlling the irradiation of food it is possible to use the method or food only after satisfying the proper authorities that the process is safe and the treated food wholesome. As far as is known, all such regulations provide for obtaining approval or clearance or exemption from the prohibition contained in the law. For example, under such a procedure the Food and Drug Administration of the United States has given clearance for unlimited consumption of irradiated bacon, irradiated wheat and wheat flour and irradiated white potatoes.

The irradiation processing of food can be carried out in different ways depending upon the objectives to be accomplished. Each of these objectives calls for a different amount, or dose, of irradiation. Some of these are illustrated by the following examples:

(1) Disinfestation of grain; in order to kill insects in the grain it is exposed to a low dose of radiation of only 15,000 to 25,000 rad. Such grain will remain indefinitely free of insects unless it becomes reinfested due to improper storage.

(2) Extension of market life:

(a) the sprouting of potatoes is inhibited by a low dose of radiation of only about 8,000 to 15,000 rad;

(b) the market life of fresh fish can be doubled, at a storage temperature of crushed ice, by a treatment of about 150,000 rad.

(3) Meats in sealed containers can be protected indefinitely against spoilage by bacteria and rendered free of hazard from bacterial pathogens by radiation dose of approximately 4.5 Mrad.

In order to accomplish such treatments radioisotopes emitting gamma radiation of certain energies, or X-rays or accelerated electrons of certain energies may be used. At present, the sources allowed for treatment under the regulations permitting the processing of bacon, wheat and potatoes are ^{60}Co, ^{137}Ce, accelerated electrons of 10 MeV and X-rays produced by an electron beam of an energy level not to exceed 5 MeV. Such energies have been demonstrated to produce no harmful effect upon the food treated and, therefore, approval for their use has been given.

Most countries that have regulations on the possession and the use of radioisotopes use this to control the possession and the use of materials cited above that may be used in food preservation. This includes also the requirements for safety of any personnel that may be working in the area where such isotopes are used. Thus, not only the treated food must be safe and wholesome, but also the safety of all phases of manufacture is assured.

The effort that has gone into the studies to assure the safety and wholesomeness of irradiated food far exceeds the time, manhours and money that has been spent on any other process or type of food product. The requirements for clearance for human consumption equal that of any other food product manufactured by any other means. The laws that cover the use of the food irradiation process are precise and exacting in their requirements. Several years of research are necessary to complete the nutritional studies on several generations of animals, the chemical enzymatic, toxicity and carcinogenic studies must show negative results by standardized procedures used in medical and nutritional research. Only after a thorough and systematic review of all of this data will clearance be given by health authorities and governmental officials. This must be done for each individual type of food. For example, clearance given for unlimited consumption in the United States did not include seeds such as beans or peas. Such items must undergo the same exacting procedure that was used for wheat.

Let us now look at the status of legislation on irradiated food in the various countries. A preliminary survey has been carried out on the laws now existing in order to gain some idea of the general form that has been used to contol this food processing method. Requests were sent to 128 Member Governments of FAO and IAEA for information on their legislation in this field. Replies were received from 60. Of this number 48 reported that they had no laws covering this particular subject of irradiated food, while 12 replied that they did have legislation.

It is not possible in these pages to discuss the regulations of the individual countries, except in certain instances to use them as illustrations, nor is it possible to make a complete analysis of the methods used in law making. Therefore, a resumé will be given of the trends that are shown in the regulations and a review of the specific foods that are presently approved for human consumption.

The countries giving information on their regulations pertaining to irradiated food were: Australia, Belgium,

Canada, France, Federal Republic of Germany, Israel, Italy, Luxembourg, Spain, Switzerland, United Kingdom and the United States.

GENERAL FORM OF LEGISLATION REPORTED

The general form of the regulations indicates that in all of the above countries it is necessary to obtain approval in some form to manufacture, possess, sell, export or import food that has been exposed to ionizing radiation. In certain countries such activities are prohibited. In other countries this is handled by a decree that sets forth the terms on which approval will be made. In some countries, irradiated food is regulated in the same way as for the use of food additives under the general principle that no food additive shall be used without approval by appropriate authorities. In all cases there is the requirement that proof be submitted that such foods are not harmful or injurious to health. In all cases there are provisions in the regulations for applying for exemptions to the regulation, upon the presentation of specified information and proof of the inocuousness of the treated food. In most cases a licence is required for the use of radioisotopes or machines for treating food with ionizing radiation. In one very interesting instance, the country does not have regulations for the production or control or irradiated food, but it does have regulations specifically permitting the importation of potatoes that have been treated with ionizing radiation for sprout inhibition.

CLEARANCE OF IRRADIATED FOOD ITEMS FOR HUMAN CONSUMPTION

The clearance of irradiated food or for food packaging materials that may be subjected to irradiation treatment has been given in only two countries according to the survey that has been mentioned. In addition, one of the countries that did not reply to the questionnaire, recently reported (FAO/IAEA, 1966) the release for human consumption of potatoes, dehydrated fruits, certain fresh fruits and vegetables and semi-finished meat products. In Canada, clearance for unlimited human consumption has been given by the Food and Drug Directorate of white potatoes and onions that have been given irradiation treatment to inhibit sprouting, at a dose not to exceed 15,000 rad. This clearance was given under regulations which classify irradiation treatment as a food additive. Irradiated items must be marked and declared as such.

Israel has recently given clearance, for human consumption, of white potatoes irradiated with ^{60}Co up to a limit of 15,000 rad. The regulations control the processing, sale or import of irradiated foods and require that the words "Food conserved by irradiation" must be clearly and legibly printed on the packaging of the product.

In the United States, irradiated products are handled under the Section on Food Additives of the Federal Food, Drug and Cosmetic Act (as amended). So far the following irradiated foods have been given clearance for unlimited human consumption:

(1) Bacon: Clearance has been given for irradiation of this item to an absorbed dose of 4.5 to 5.6 Mrad, by the use of sealed radiation sources of ^{60}Co or ^{137}Ce, or accelerated electrons not to exceed an energy of 10 MeV, or by X-rays produced by an energy not to exceed 5 MeV.

(2) Wheat and wheat products: These products have been given clearance for absorbed irradiation doses in the range of 20,000 to 50,000 rad by the use of sealed radiation sources of ^{60}Co or ^{137}Ce, or accelerated electrons at energies not to exceed 5 MeV.

(3) White potatoes: Clearance for consumption has been given for this product at absorbed irradiation dose of 5,000 to 10,000 rad. This was later increased to a maximum of 15,000 rad. Sealed radiation sources of ^{60}Co and ^{137}Ce have been approved.

Irradiated products such as these must be labelled as "Processed by ionizing radiation" or "Processed by gamma radiation", "Processed by electron radiation" or "Processed by X-radiation", as the case may be.

Clearance of packaging materials

Under most national regulations, food packaging materials must undergo the same general type of testing as the irradiated food. As a result of intensive research and testing on irradiated packaging materials, the Food and Drug Administration in the United States has given clearance for the following:

(1) polyethylene film prepared from basic polymers and with or without added approved substances;
(2) polyethylene terephthalate film with or without added approved substances;
(3) nylon 6 films with or without added approved substances;
(4) vinyl chloride–vinyl acetate copolymer with or without added approved substance;
(5) cellophane, nitrocellulose-coated or vinylidine chloride copolymer-coated;
(6) glassine paper;
(7) wax-coated paperboard;
(8) polypropylene film;
(9) ethylene-alkene-1 copolymer film;
(10) polystrene film;
(11) rubber hydrochloride film;
(12) vinylidene chloride copolymer;
(13) vegetable parchment;
(14) Kraft paper as a container for irradiated wheat flour.

Clearance of radiation sources used for inspection of food

The use of radioisotopes of X-rays in industry has become common practice and the food industry has found their use both efficient and economical for such things as (a) the inspection of food, such as the use of X-ray to detect quality defects in the centre of oranges, (b) to determine the compliance of packaged material with the requirements for fill of food packages or bottled goods, such as beer, and (c) to control automatically certain food processing operations.

In the United States, the following radiation sources have been approved for use in the food industry, not for the irradiation treatment of food but for quality and operational control of the following sources:

(1) X-ray tubes producing X-radiation at energy levels of 300 kV peak or lower;
(2) sealed units producing radiation at levels of not more than 2.2 MeV from one of the following isotopes: ^{137}Ce, ^{60}Co, ^{85}Kr, ^{226}Ra and ^{90}St.

It is required that no food shall be exposed to such radiation sources so as to receive an absorbed dose in excess of 1,000 rad.

COMMENTS

It must be pointed out that on a world basis the information presented is not complete as it is based only upon material presented by the various governments that responded to a request for information on legislation. It was reported by several countries that, while they did not have regulations to control the irradiation of food, they were considering the subject or were in the process of preparing legislation. It is believed that in the near future several countries will join the group listed above as having legislation in this field.

Reference

FAO/IAEA Symposium on Food Irradiation, Karlsruhe. 1966

Status of Research on Irradiated Fish and Shellfish in the United States

by L. J. Ronsivalli, J. D. Kaylor and J. W. Slavin

Status of research on irradiated fish and shellfish in the United States

This paper reviews the status of technical and commercialization research on radiation-pasteurization of fish and shellfish in the United States.

The authors discuss: (a) the results of laboratory studies on organoleptic, microbiological, and wholesomeness aspects of irradiated seafoods; (b) developmental investigations on irradiating fish ashore and at sea; and (c) a study of the process under commercial conditions.

Completed research in many laboratories has shown the efficacy of the process which extends the product shelf life by one to two weeks and reduces the total plate count by one to three log cycles. Other factors which affect the product shelf life and the composition of the microflora in the product (storage temperature, initial product quality, packaging, bacteriostatic salts and oxygen availability) are discussed.

Fish irradiation at sea appears advantageous.

The authors compare irradiated, spoiled product with non-irradiated spoiled product and describe a concept for determining whether a botulism hazard exists in radiation-pasteurized fish.

The authors believe that radiation-pasteurized fish are as safe and wholesome as untreated fresh fish

Studies to test the commercial applicability of the process using a 250,000 ci Cobalt-60 irradiator at Gloucester, Massachusetts, showed the process is efficacious and would be extremely valuable to industry. A survey indicates probable consumer acceptance of irradiated foods. Using commercial packing and shipping methods, it was found that radiation-pasteurized fish can be handled in the same manner as fresh fish, and the extended shelf life made possible with irradiation permits shipments to very distant points in the country. Results obtained by co-operating members of the industry representing about 9,000 retail markets indicate that irradiation will: (1) reduce waste and price cutting; (2) increase sales and expand markets for fresh seafoods; (3) result in overall higher quality products and lower costs for the consumer; and (4) will increase profits for industry.

Situation actuelle de la recherche sur l'irradiation du poisson et des crustacés et mollusques aux Etats-Unis d'Amérique

La communication passe en revue la situation actuelle de la recherche, dans le domaine technique et dans celui de la commercialisation, sur la radio-pasteurisation du poisson et des crustacés et mollusques aux Etats-Unis d'Amérique.

Les auteurs examinent: (a) les résultats d'études faites en laboratoire sur les produits marins irradiés des points de vue des qualités organoleptiques, de la microbiologie et de l'innocuité; (b) les travaux sur les procédés d'irradiation des produits de la pêche à terre et en mer; (c) l'étude de la technique de l'irradiation dans les conditions commerciales.

Les recherches menées à terme dans nombre de laboratoires démontrent l'efficacité d'un procédé qui allonge la conservabilité du produit de une à deux semaines et réduit la nombre total de bactéries de un à trois modules logarithmiques. Les auteurs traitent d'autres facteurs affectant la faculté de conservation du produit et la composition de sa microflore: température d'entreposage, qualité initiale du produit, conditionnement, sels bactériostatiques et disponibilité en oxygène.

L'irradiation en mer semble présenter des avantages.

Les auteurs comparent deux produits altérés, dont l'un a été irradié et l'autre non, et décrivent un moyen de déterminer si le poisson radio-pasteurisé présente un danger de botulisme.

Les auteurs estiment que le poisson pasteurisé par irradiation présente les mêmes qualités de comestibilité que le poisson frais non traité.

Un procédé utilisant un irradiateur au Cobalt-60 de 250 000 curie situé à Gloucester (Massachusetts) s'est révélé, après essais, efficace et extrêmement intéressant pour l'industrie. Après enquête, il semble que les produits alimentaires irradiés seront bien acceptés par les consommateurs. On a constaté que, si l'on a recours aux méthodes commerciales de conditionnement et d'expédition, le poisson radio-pasteurisé peut être traité comme le poisson frais, et la prolongation de conservabilité due à l'irradiation permet de livrer à de très grandes distances.

Sur la base des résultats obtenus par les membres de l'industrie ayant participé à l'enquête (qui représentent environ 9 000 points de vente au détail), on a conclu que l'irradiation présente les avantages suivants: (1) réduction des déchets et de la dépréciation; (2) accroissement des ventes et expansion des débouchés pour les produits marins frais; (3) vente au consommateur, à plus bas prix, de produits de qualité supérieure dans l'ensemble; (4) augmentation des bénéfices pour l'industrie.

El estado de las investigaciones sobre el pescado y los mariscos irradiados en los Estados Unidos

En este trabajo se examina el estado de las investigaciones técnicas y comerciales sobre la pasterización por irradiación del pescado y los mariscos en los Estados Unidos.

Los autores examinan: (a) los resultados de los estudios de laboratorio sobre los aspectos organolépticos, microbiológicos y sanitarios de los alimentos marinos irradiados; (b) las investigaciones sobre el pescado irradiado en tierra y en el mar; y (c) un estudio del procedimiento en condiciones comerciales.

Las investigaciones ya acabadas en muchos laboratorios han mostrado la eficacia de este procedimiento que amplía la vida de mantenimiento del producto en almacén en 1–2 semanas y reduce el recuento bacteriano total en placa en 1–3 ciclos logarítmicos. Se examinan otros factores que influyen en la duración de la conservación en almacén del producto y en la composición de la microflora en el mismo (temperatura de almacenamiento, calidad inicial del producto, envasado, sales bacteriostáticas y disponibilidad de oxígeno).

Parece ventajosa la irradiación del pescado en el mar.

Los autores comparan el producto irradiado deteriorado con el producto no irradiado deteriorado y desarrollan un concepto para determinar si existe riesgo de botulismo en el pescado pasterizado por irradiación.

Los autores estiman que el pescado pasterizado por irradiación es tan inocuo y sano como el pescado fresco no tratado.

Los estudios realizados en Gloucester, Massachusetts, para probar la aplicabilidad comercial del procedimiento usando un irradiador de Cobalto-60 de 250.000 curies, indicaron que aquél es eficaz y que sería extremadamente valioso para la industria. Una encuesta ha indicado que es probable que los consumidores acepten los alimentos irradiados. Usando métodos comerciales de envasado y de envío se halló que el pescado pasterizado por irradiación se puede manipular del mismo modo que el pescado fresco, y que la mayor duración en almacén hecha posible con la irradiación permite efectuar envíos a puntos muy distantes del país. Los resultados obtenidos por los miembros cooperadores de la industria que representan a unos 9.000 mercados al por menor indican que la irradiación: (1) reducirá los desperdicios y las bajas de precio; (2) aumentará las ventas y ampliará los mercados de productos marinos frescos; (3) hará que sea mejor la calidad de los productos y más bajos los costos al consumidor; y (4) aumentará los beneficios de la industria

THE United States Atomic Energy Commission's programme on radiopasteurization of fish and shellfish formally began in 1960 with a feasibility study by Proctor *et al.* (1960), followed by specific outlines of project proposals dealing with wholesomeness, quality and economics by Nickerson *et al.* (1960).

The Proceedings of the International Conference on Radiation Preservation of Foods (1965) and the reports of the United States Congressional Subcommittee on Atomic Energy (1965, 1966), provide a comprehensive review of progress in the United States food irradiation programme, including sea foods, up to September 1966. These reports were supplemented by reviews on the radiation pasteurization of fish and shellfish (Slavin *et al.*, 1966a; Slavin, Ronsivalli and Kaylor, 1965a; Steinberg, 1965). The most recent paper by Slavin, Ronsivalli and Connors, (1966b) covered the status of research and development of radiation-pasteurization of fish and shellfish in the United States. According to the latter paper, the feasibility of radiopasteurizing 19 species of fish and shellfish has been adequately demonstrated.

Since these are rather complete reviews, the discussions in this paper are limited to an evaluation of technical progress and development toward the commercialization of radiation-pasteurized sea foods.

TECHNICAL PROGRESS

The evidence of the efficacy of radiation energy for preserving foodstuffs has been known for some time, as it also has been known that the mechanism of radiation preservation involves a reduction in the microflora which inhabits the food. It has been found (Slavin *et al.*, 1965b) that pasteurizing doses of radiation reduce the bacterial numbers by one to three log cycles. There is good reason to believe that the effect depends on the dose level applied and the composition of the flora. Figure 1 illustrates the effect of different levels of radiation on the total plate count in dover sole (*Microstomas pacificus*). This effect in extending the product shelf life is shown in fig 2. Other factors which affect the composition and size of the microflora are the type of packaging used, availability of oxygen, storage temperature, salts and pre-irradiation quality, etc.

Licciardello, Ronsivalli and Slavin (1966), Sinskey *et al.* (1967), Tinker, Ronsivalli and Slavin (1966), and others have shown that reducing the oxygen availability in packaged radiopasteurized fish and varying the type of packaging used resulted in major changes in the microflora. Spencer and Baines (1964) reported that the spoilage rate in white fish was tripled when the storage temperature was increased 10°C (50°F) in the range of −1° to 25°C (30° to 77°F). Recent radiopasteurization research indicated the spoilage rate in irradiated fish was approximately doubled when the storage temperature was increased about 5 degC (9 degF) from about 0.6°C (33°F) to about 5.6°C (40°F). Synergistic, preservative effects were noted when radiation was combined with heat (Licciardello, 1963; Nickerson, 1964) or with sodium benzoate, potassium sorbate, and sodium salts of methyl and propyl esters of para-hydroxybenzoic acids (Sinnhuber and Lee, 1964). Although total plate counts were reduced as a result of irradiation, the total plate count in

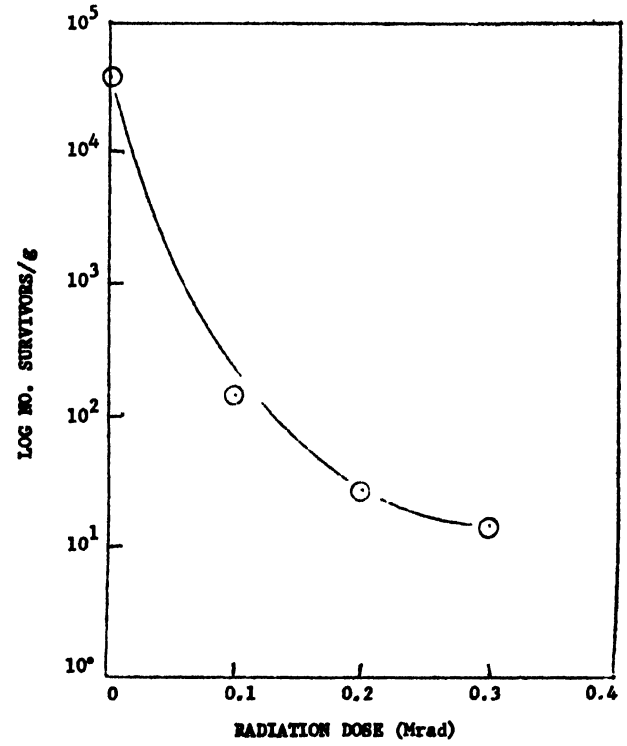


Fig 1. Effect of different pasteurizing radiation doses on the total plate count in dover sole — from Sinnhuber and Lee (1965)

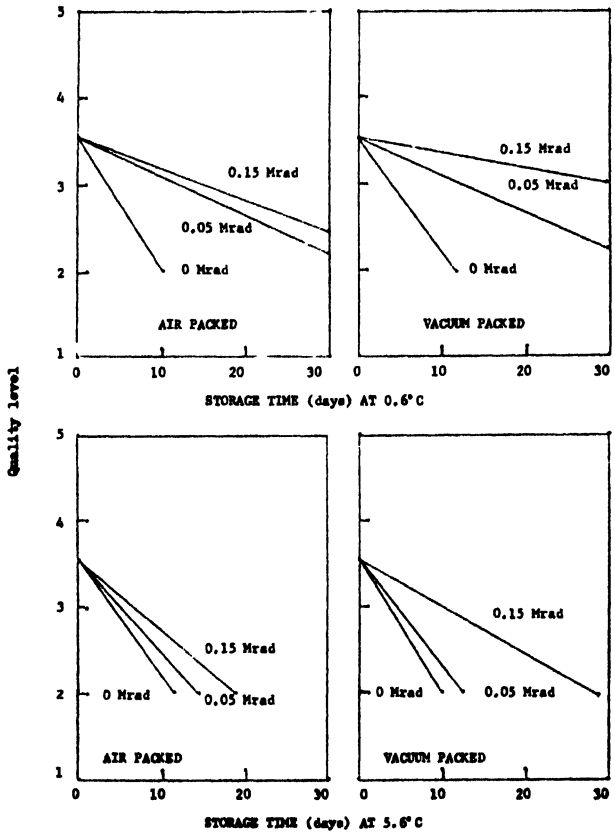


Fig 2. Effect of different radiation doses on quality degradation rates of air and vacuum-packed haddock (Melanogrammus aeglefinus) *fillets stored at 0.6° and 5.6°C; 5, excellent; 4, very good; 3, good; 2, fair; 1, poor*

TABLE 1. SPOILAGE CHARACTERISTICS AND SHELF LIFE OF IRRADIATED (150,000 RAD) AND NON-IRRADIATED COD FILLETS STORED AT DIFFERENT TEMPERATURES

Sample	*Storage temperature (°C)*	*Shelf life of product served steamed (days)*	*Comments of panel*	
			Cooked evaluation at end of shelf life	*Raw evaluation at end of shelf life*
Irradiated in air-packed cans	0.6	36	Off odour, musty, old	Persistent fishy odour, slight discolouration
	2.8	15	Ammonia, bitterness	Opaque, defects, discoloured, fishy odour
	5.6	12	Irradiation taste, bitter burnt taste	Slight irradiation odour, slight fishy odour
	8.3	12	Ammonia, putrid, inedible	Defects, discolouration, slight irradiation odour, fishy odour
Irradiated in bulk-packed 30-lb (13.6-kg) tins	0.6	36	Spoiled, irradiation odour, irradiation flavour, ammonia	Slight discolouration, slight fishy odour, slight irradiation odour
	2.8	15	Putrid, ammonia, irradiation odour	Defects, discoloured, fishy odour
	5.6	12	Musty, rancid	Slight fishy odour
	8.3	12	Ammonia, stale odour	Defects, discolouration, irradiation odour, decomposition odours
Non-irradiated, bulk-packed in 30-lb (13.6-kg) tins	0.6	15	Ammonia, putrid, sour, inedible	Defects, discoloured, persistent fishy odour
	2.8	12	Ammonia, inedible, putrid	Defects and discoloured
	5.6	12	Ammonia, putrid, sour, bad, rancid	Defects, discoloured, decomposition odours
	8.3	5	Ammonia	Decomposition odours

irradiated fillets at the end of their shelf life was several to 100 times greater than that in non-irradiated fillets at the end of their shelf life. This is not surprising if we recognize that pseudomonads play a major role in the spoilage of fish (Licciardello, Ronsivalli and Slavin, 1966; Adams, Farber and Lerke, 1964) and others, and that pseudomonads are highly active biochemically (Castell and Maplebeck, 1952), but are highly susceptible to irradiation (Thornley, 1963) and, thus, are virtually non-existent in the microflora of spoiling irradiated fillets (Corlett, Lee and Sinnhuber, 1965). Although it would appear that one should expect differences between the odours of spoiled, irradiated fish and the odours of spoiled non-irradiated fish, there is no evidence for this. In fact, similarities have been found in the objectionable odours of spoiled irradiated and non-irradiated cod fillets, see table 1. Similar data were reported by Goldblith and Nickerson (1965). The effect of pre-irradiation quality on the post-irradiation shelf life of fillets has been investigated (Ampola and Ronsivalli, 1967), and the findings are summarized in fig 3. The relationship exhibited by this figure indicates the broad applicability of irradiation with respect to initial product quality, but it also implies that irradiation should be applied as soon as possible and, in this connection, studies are presently underway to determine the desirability of radiopasteurizing fish at sea. Preliminary results reported earlier indicate that fish irradiated at sea in the *pre-rigor* state maintain a better quality throughout the storage period, see fig 4; as yet we are not able to explain this, however. The present objective in this study is to determine whether one can use lower doses (<100 krad) at sea to achieve the same preservative effects obtained on land with standard radiopasteurization doses (150 to 200 krad). This notion is based on the assumption that fish at sea have a much lower bacterial load and require less treatment.

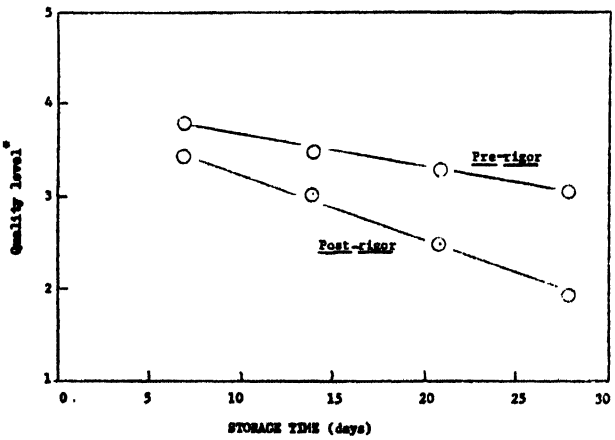


Fig 3. Quality comparison between cod (Gadus morhua) *irradiated pre-rigor and cod irradiated post-rigor. Radiation dose level was 0.1 Mrad. 5, very good; 4, good; 3, fair; 2, borderline; 1, poor*

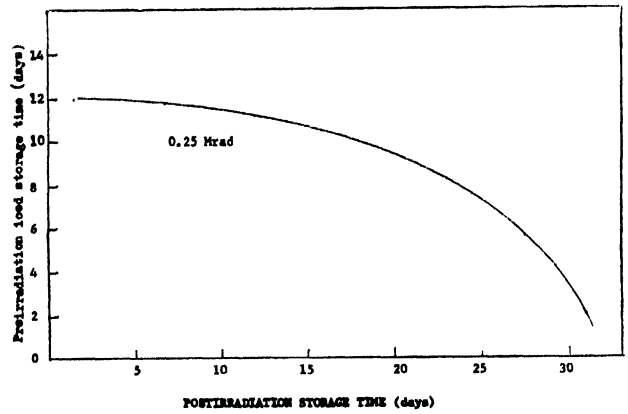


Fig 4. Effect of pre-irradiation quality of iced eviscerated haddock (Melanogrammus aeglefinus) *on the post-irradiation shelf life of the fillets stored at 0.6°C*

Before the benefits of radiopasteurization can be realized, it is necessary to obtain approval of the process by the USFDA. Precedent for the use of irradiation to preserve foods was set with the approval for radiosterilizing bacon at 5.5 Mrad, and there is no apparent need to discuss the safety of irradiation as an additive. However, the incidences involving *Clostridium botulinum* type E in fishery products, and lack of information on the factors which contribute to its growth in fish, raised concern about the likelihood of botulinum toxin development in fish treated with sub-sterilizing doses of radiation.

Thus far the natural occurrence of this organism in fish has not been defined quantitatively. Some available data indicate variable but very low incidence. Goldblith and Nickerson (1965) found the natural occurrence of total clostridia to be about 0.17 organisms per gram of fish flesh in a limited study carried out on the east coast of the United States. This amount, even if it were all type E botulinum organisms, is approximately 100,000 times less than that required to produce toxin at 7.2°C (45°F) in haddock (*Melanogrammus aeglefinus*) fillets according to the authors. The occurrence of *Clostridium botulinum* in nature was recently discussed by Foster and Sugiyama (1966). The role of *Clostridium botulinum* should be appraised in a manner which will permit an accurate and objective evaluation of any possible public health hazard. Some recent studies which indicate that toxin can be produced in inoculated packs have little significance because of the extremely high inoculum levels used and the failure to consider the interval between the times of recognizable spoilage and toxin development as a factor of safety in non-irradiated as well as irradiated fish. Studies are presently underway in various laboratories throughout the United States to establish the safety factors which exist for non-irradiated fish and for fish irradiated at different levels and stored at different temperatures. The data derived from these studies should provide the means to properly judge this aspect of radiation safety as illustrated in fig 5. In this case, the

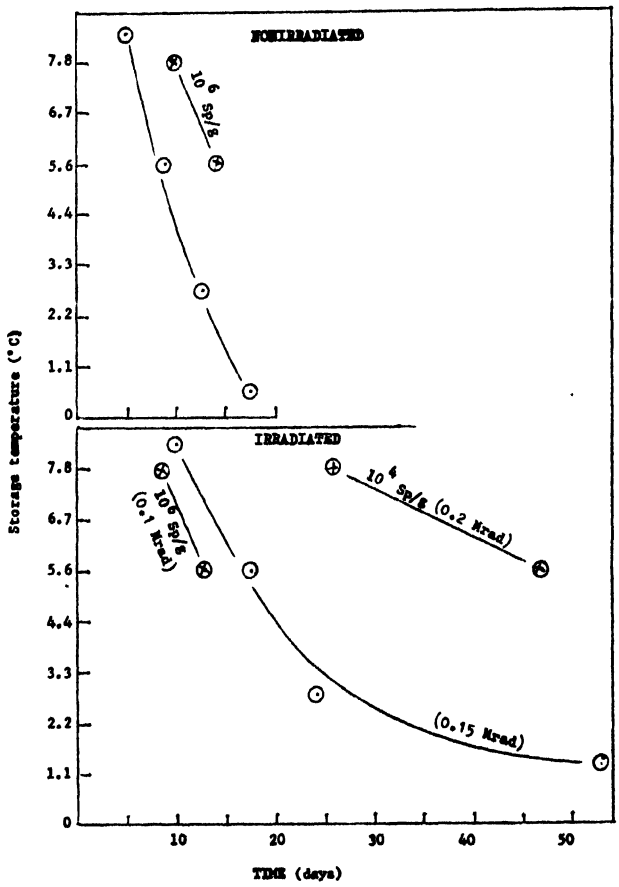


Fig 5. Maximum shelf life and type E botulinum *toxin development in irradiated and non-irradiated cod* (Gadus morhua) *fillets.* ⊙, *Shelf life based on odour of raw sample;* ⊗, *toxin development: inoculum level in spores/g (Sp/g)*

times at which the product was spoiled are compared with the times at which botulinum toxin appeared as a function of storage temperature.

As expected, the samples inoculated at the higher levels developed toxin first and, as pointed out earlier, samples inoculated with 10^2 spores/g of *Clostridium botulinum* type E did not develop toxin at all. The data further suggest that the toxin outbreak time, as well as the product shelf life, is increased as a function of applied irradiation dose. Indications of present research are that haddock and cod (*Gadus morhua*) fillets inoculated with up to 10^4 spores/g will undergo spoilage and be rejected well in advance of toxin development.

COMMERCIALIZATION

Public health clearance, product performance, market desirability and economics are essential considerations in evaluating the application of radiation treatment of fishery products.

Public health clearance

Commercialization of radiation-treated seafoods will not be possible until the United States Food and Drug Administration grants clearance for general sale of foods preserved by low-level ionizing radiation. A formal petition presenting scientific evidence aimed at securing Food and Drug approval was submitted in July 1965. An amendment to the petition, which provides additional evidence of the ability of the radiation-treated fillets to withstand commercial shipping methods, is now being compiled. The petition specifies radiation levels of 200 krad (0.2 Mrad) and packaging and handling methods common to the fresh fish industry, using long established efficacious normal refrigeration practices.

Animal feeding studies are being conducted in preparation for submission of a petition for clearance of soft shell clam meats. The necessary data is being gathered to support petitions to obtain eventual Food and Drug clearance for clams, crabmeat, oysters and shrimp.

Product performance

The aim of low-level radiation treatment of fishery products is to extend the shelf life of irradiated fillets a week or more over that of similar non-irradiated fillets. Early radiation literature established a shelf life of two to four weeks for irradiated fillets held under controlled laboratory conditions. To test the laboratory findings, we have repeatedly made shipments of many hundred pounds of fillets of cod, flounder (*Pleuronectes flesus*), haddock and sole (*Solea solea*) irradiated under commercial conditions and which were handled and shipped under commercial conditions using common carriers (trains and trucks) for distances of about 2400 to 4800 km. Under these commercial conditions, fillets irradiated at 200 krad were found to have the added shelf life of a week or longer over that of similarly handled non-irradiated fillets. This extension of shelf life would be reflected at all levels in the chain of distribution as it now exists in the United States.

Market desirability

Quality evaluations by about 15 industry firms and supermarket chain stores representing some 9,000 retail

markets corroborate our laboratory findings. They have indicated that the irradiated product remains at a high level of quality a week or more longer than non-irradiated control samples when handled under the same commercial conditions. The chain store seafood buyers have expressed interest in the radiation process (Kaylor, 1966) and have declared it to be a desirable process, provided the potential consuming public has no aversion to radiation-treated seafoods. Acceptability tests conducted at Fort Lee, Va., in co-operation with the United States Army Natick Laboratories and by other voluntary industry groups, also indicate the acceptability of radiation treated fillets (tables 2 and 3).

ance of the process. The restaurant trade preferably and traditionally buys fresh fish and is considered to be a potentially very large user of radiation-treated seafoods. The nature of the restaurant trade is such that it will not be hampered by considerations of labeling. In view of this, its requirements, at first, might well outstrip those of the supermarket or other retail outlets until public acceptance is firmly established.

Economics

At present, all cost estimates of low-level food radiation processing are speculative because no food irradiation is being performed on a truly commercial basis. A report on

TABLE 2. ACCEPTABILITY TESTS ON RADIATION-PASTEURIZED SEAFOOD (UNITED STATES ARMY TEST AND EVALUATION COMMAND, FORT LEE, VA.)

Product	*Panel members (No.)*	*Dose (Mrad)*	*Storage temperature (°C)*	*Storage period (days)*	*Average taste scores**	
					Irradiated	*Non-irradiated frozen controls*
Haddock fillets†	314	0.25	0.6	15	5.76	6.13
				29	5.80	6.17
Petrale sole fillets†	333	0.20	0–1.7	16	5.90	6.43
				28	6.52	6.57
Haddock fillets‡	693	0.15	0.6	7	6.19	5.90
				14	5.99	6.19
Cod fillets‡	588	0.15	0.6	17	6.59	6.54
				24	6.31	6.23

* Based on hedonic scale where: 9, like extremely; 8, like very much; 7, like moderately; 6, like slightly; 5, neither like nor dislike; 4, dislike slightly; 3, dislike moderately; 2, dislike very much; 1, dislike extremely.
† Packed in air, hermetically-sealed cans.
‡ Packed in 30-lb (13.6-kg) fillet tins to approximate commercial conditions.

TABLE 3. ACCEPTABILITY SCORES* BY DIFFERENT PANELS OF RADIATION-PASTEURIZED SEAFOODS HELD AT 0.6°C FOR ABOUT TWO WEEKS

Panel	*Panel members (No.)*	*Fried haddock*	*Lobster salad*	*Clam chowder*	*Cod fillets*
Gloucester (trained)	14	7.4	8.4	7.7	6.0
Consumer type	278	7.2	7.7	6.4	—
Natick (trained)	8	—	—	—	6.5
Natick (consumer type)	36	—	—	—	6.9

* Based on hedonic scale where: 9, like extremely; 8, like very much; 7, like moderately; 6, like slightly; 5, neither like nor dislike; 4, dislike slightly; 3, dislike moderately; 2, dislike very much; 1, dislike extremely.

There are two broad markets for consumption of fishery products in the United States. They are classified as (1) chain store supermarkets or other retail stores; (2) institutional or restaurant trade. According to a cost-benefit study (Yankelovich, 1966) made for the Atomic Energy Commission, intensive interviewing of consumers throughout the United States revealed that response to the concept of irradiated foods without any education as to the radiation process, showed a surprising degree of acceptance (53 per cent). After information was provided to them, 82 per cent indicated acceptance if Food and Drug Administration approval of the process is granted. The same study of the trade and institutional field revealed that a similar acceptance prevailed.

At the present time we do not know which of the two markets will absorb the greater amount of radiation-treated seafoods. The chain supermarkets and retail stores group has a large potential for sales, but any sales projection must be tempered by the amount of favourable or unfavourable publicity attendant upon eventual clear-

the Marine Products Development Irradiator (MPDI) (Slavin and Miller, 1964) indicates that radiation costs may be approximately U.S. $0.02 per lb of product (about U.S. $0.04/kg). This estimate is based upon the present semi-commercial MPDI and does not consider estimated costs of a full-size commercial irradiator. We estimate that the latter should have at least double the production capacity of our present MPDI, with a consequent cost reduction of about U.S. $0.005 per lb of product (approximately U.S. $0.01/kg). Packaging materials used for irradiated fillets would be essentially the same as those used presently and would entail no extra cost. Shipping and handling costs for irradiated fillets would be identical with fresh fillets, as there would be no change in present practices. The benefits conferred by irradiation include:

(1) reduction of waste or price-cutting to avoid week-end carryover;
(2) increased sales of fresh seafoods;
(3) consistently higher level of freshness than is now available;
(4) ability to pass along savings to consumers;
(5) increased profits;
(6) expansion to areas not now selling fresh fish.

References

ADAMS, R, FARBER, L and LERKE, P 1964 Bacteriology of spoilage of fish muscle. *Appl. Microbiol.*, 12(3), 277–279.

AMPOLA, V G and RONSIVALLI, L J 1967 Effect of preirradiation quality of eviscerated haddock on the postirradiation shelf life of the fillets. *Fd Technol.* (MS.)

CASTELL, C H and MAPPLEBECK, E G The importance of
1952 flavobacterium in fish spoilage. *J. Fish. Res. Bd Can.*, **9**(3), 148–156.

CORLETT, D A, JR, LEE, J S and SINNHUBER, R O Application
1965 of replica plating computer analysis for rapid identification of bacteria in some foods. *Appl. Microbiol.*, **13**(5), 18.

FOSTER, E M and SUGIYAMA, H Latest developments in
1966 research on botulism, *Milk and Food Technology*, **11**, 342–347.

GOLDBLITH, S A and NICKERSON, J T R The effect of gamma
1965 rays on haddock and clams inoculated with *Clostridium botulinum* type E, Final Rpt. to Div. of Biol. and Medicine, USAEC, Contract No. AT(30–1)–3325.

JOINT COMMITTEE ON ATOMIC ENERGY *Hearings before the*
1965 *Subcommittee on Research, Development, and Radiation of the Joint Committee on Atomic Energy, Congress of the United States*, U.S. Govt. Printing Office, Washington, D.C.

JOINT COMMITTEE ON ATOMIC ENERGY *Ibid., 89th Congress of*
1966 *the United States*, U.S. Govt. Printing Office, Washington, D.C.

KAYLOR, J D Commercial prospects for radiopasteurized
1966 seafoods, Sixth Annual AEC Food Irradiation Contractors' Meeting, Washington, D.C.

LICCIARDELLO, J J Complementary effects of thermal and
1963 ionizing energy. In *Exploration in Future Food Processing*, ed. S. A. Goldblith, M.I.T. Press, Cambridge, Mass, chapter 4.

LICCIARDELLO, J J, RONSIVALLI, L J and SLAVIN, J W Effect of
1966 oxygen tension on the microflora of irradiated and non-irradiated haddock fillets. *J. appl. Microbiol.* (MS.)

NATIONAL ACADEMY OF SCIENCES. *Radiation Preservation of*
1965 *Foods*, Proc. Int. Conf., NAS–NRC, Pub. 1273, Washington, D.C.

NICKERSON, J T R Simultaneous radiation heating treatment
1964 of haddock. Presented at the 4th Annual USAEC Contractors' Meeting on Radiation Preservation of Foods, Washington, D.C.

NICKERSON, J T R, GOLDBLITH, S A, MILLER, S A, LICCIAR-
1960 DELLO, J J and KAREL, M Outline of projects to determine the feasibility of radiation preservation of marine products, Rpt. No. NYO9183, Task X, Contract No. AT(30–1)–2329, USAEC.

PROCTOR, B E, GOLDBLITH, S A, NICKERSON, J T R and
1960 FARKAS, F F Evaluation of the technical, economic, and practical feasibility of radiation preservation of fish, Rpt. No. NYO9182, Task VI, Contract No. AT(30–1)–2329, USAEC.

SINNHUBER, R O and LEE, J S *Progress Report* Nos. 7, 17 and
1964 18 to USAEC under Contract No. AT(04–3)–502.

SINNHUBER, R O and LEE, J S Effect of irradiation on the
1965 microbial flora surviving irradiation pasteurization of seafoods. *Ann. Rpt. to Div. of Isotopes Development, USAEC*, under Contract No. AT(04–3)–502, 21.

SINSKEY, T J, PABLO, I S, SILVERMAN, C J and RONSIVALLI, L J
1967 The influence of packaging on the microbial flora of irradiated haddock. *Nature, Lond.*, 213, 425–426.

SPENCER, R and BAINES, C R The effect of temperature on the
1964 spoilage of wet white fish. *Fd Technol., Champaign*, **18**(5), 175.

SLAVIN, J W and MILLER, P Irradiation nears reality. *Fd*
1964 *Engng.*, **36**(1), 92.

SLAVIN, J W, RONSIVALLI, L J and KAYLOR, J D Radio-
1965a pasteurization of fishery products. *Activities Rpt*, Natick, Mass., U.S. Army Natick Laboratories, **17**(2), 120.

SLAVIN, J W, RONSIVALLI, L J, KAYLOR, J D and CARVER, J H
1965b Study of Irradiated-Pasteurized Fishery Products. *Annual Report to USAEC*, TID-22833, Contract No. AT(49–11)–1889, p. 29.

SLAVIN, J W, NICKERSON, J T R, GOLDBLITH, S A, RONSIVALLI,
1966a L J, KAYLOR, J D and LICCIARDELLO, J J The quality and wholesomeness of radiation pasteurized marine products with particular reference to fish fillets. *Isotopes and Radiation Technology*. (MS.)

SLAVIN, J W, RONSIVALLI, L J and CONNORS, T J The status
1966b of research and development of radiation pasteurization of fish and shellfish in the United States. Presented at the International Symposium on Food Irradiation, Karlsruhe. *Fd Irrad.* (MS.)

STEINBERG, M A Atom preserves seafoods. *Proceedings of*
1965 *Gulf and Carribean Fisheries Institute*, Miami, Florida.

THORNLEY, M J Radiation resistance among bacteria. *J. appl.*
1963 *Bact.*, **26**, 334.

TINKER, B L, RONSIVALLI, L J and SLAVIN, J W Suitability of
1966 flexible plastics as packaging materials for radiopasteurized seafoods. *Fd Technol., Champaign*, **20**(10), 122–124.

YANKELOVICH, D Cost benefits study of selected products in
1966 Atomic Energy Commission's low-dose food irradiation program. *Report to the USAEC*, No. NYO–3666–1, Contract No. AT(30–1)–3666.

Present Status of Radiation Preservation of Fish and Fishery Products in Europe

by G. Hobbs and J. M. Shewan

Present status of radiation preservation of fish and fishery products in Europe

The potential applications of radiation pasteurization of fish are discussed in the light of feasibility, cost and potential health hazards. There are areas such as the marketing of unfrozen packaged fish, where radiation could be used to advantage within the present marketing systems existing in Western Europe. The potential increase in hazard from botulism requires a more critical examination, however, before such a process would be acceptable. Another promising application is in the decontamination of imported fish meals. Whilst radiation sterilization is not yet a feasible process, further research may lead to the development of a suitable process in combination with heat and chemical additives.

Situation actuelle de la conservation du poisson et des autres produits de la pêche par l'irradiation en Europe

Les applications éventuelles de la pasteurisation du poisson par l'irradiation sont examinées compte tenu des possibilités, du coût et des risques pour la santé. Il existe des secteurs, comme celui de la commercialisation du poisson emballé non congelé, où l'irradiation pourrait rendre des services dans le cadre des systèmes de commercialisation actuels d'Europe occidentale. Etant donné toutefois la possibilité d'un accroissement du risque de botulisme, le procédé ne saurait être adopté sans une étude critique plus poussée. Une autre application prometteuse est offerte par la décontamination des farines de poisson importées. Si la stérilisation par l'irradiation n'est pas encore réalisable, la poursuite des recherches pourrait aboutir à la mise au point d'un procédé adéquat, conjugué avec l'emploi de la chaleur et d'additifs chimiques.

El estado actual de la conservación por radiación del pescado y de los productos pesqueros en Europa

Teniendo en cuenta la factibilidad, los gastos y los posibles riesgos para la salud, se examinan las aplicaciones potenciales de la pasterización del pescado mediante radiaciones. Existen sectores tales como los del comercio del pescado envasado no congelado en donde las radiaciones se podrían usar ventajosamente dentro de los presentes sistemas de comercialización que existen en Europa Occidental. Sin embargo, el aumento potencial de los riesgos del botulismo exige un examen más crítico antes de que sea aceptable tal procedimiento. Otra aplicación prometedora reside en la descontaminación de las harinas de pescado importadas. Aunque la esterilización mediante radiaciones no es todavía un proceso viable, ulteriores investigaciones pueden conducir al desarrollo de un proceso adecuado en combinación con el empleo del calor y aditivos químicos.

IT has long been recognized from laboratory experiments that many fish and fishery products can be preserved by irradiation. Despite the large amount of work that has been done on this method of preservation, however, no irradiated fish is yet available commercially.

Sterilization by irradiation is not yet feasible because of the undesirable organoleptic changes that occur. Radiation pasteurization or radurization at doses of 0.3 to 0.5 Mrad or less can provide worthwhile extensions of shelf life without detectable undesirable changes. It is acknowledged that such a process would be economically feasible and the only doubt preventing its use is the possibility of an increased health hazard.

In the present publication the accomplishments of radiation preservation of fishery products are discussed and related to possible commercial uses, especially in Europe.

STERILIZATION

It is generally recognized that because of the possible presence of *Cl. botulinum*, types A and B, sterilization of foods by irradiation requires doses in the region of 4 to 6 Mrad. This level of irradiation introduces unacceptable odours and flavours into fishery products.

In order to sterilize fish by this means, and still produce an acceptable commodity, some means of increasing the sensitivity of bacteria and reducing the undesirable side effects has to be found. An acceptable level of irradiation from the organoleptic point of view is in the region of 0.3 to 0.5 Mrad for most fishery products (Shewan, 1966). On this basis the sensitivity of bacteria to irradiation has to be increased by several orders of magnitude, or the undesirable changes inhibited thus permitting the use of higher doses.

It is known that certain chemicals will inhibit some of the secondary effects of irradiation, such as ascorbic acid (Hansen and Jørgensen, 1967). Also certain chemicals are known to increase the sensitivity of some micro-organisms to irradiation, e.g. nitrites, nitrates, sodium chloride, antibiotics (Anderson, Corlett and Krabbenhoft, 1967; Farkas, Kiss and Andrássy, 1967; Roberts, 1967). Using *Cl. botulinum*, types A and B, as test organisms, Anderson, Corlett and Krabbenhoft (1967) showed that sterilization could be achieved using certain additives, with dose levels of 2.0 to 2.5 Mrad. Since *Cl. botulinum* type E is much more sensitive to irradiation than types A and B, the combined use of such additives and irradiation could possibly be used to eliminate type E from fishery products. In some of our own work we have found that 10^6 spores of type E per gram of fish can be killed by doses in the region of 2.0 to 2.5 Mrad without any additives. If suitable additives had a similar effect to that described by Anderson *et al.* (1967) in meat then it is conceivable that type E could be eliminated from fish using pasteurizing doses.

If chemical additives act by increasing the amount of free radicals, and the increase in sensitivity of the bacteria is in fact due to an increased amount of free radical activity in the medium, then any advantage gained would be offset by a similar increase in the undesirable organoleptic changes in the fish. It is not clear from the published

work whether this effect does in fact occur. That free radical activity plays a major part in both killing bacteria and in producing the undesirable organoleptic changes there is no doubt. There are, however, other factors involved and it remains to be seen if some suitable combination of irradiation, heat and chemical additive will give an acceptable sterile product.

From the data available on destruction of *Cl. botulinum* toxins by irradiation, complete inactivation of preformed toxin in foods cannot be expected with practical doses (Miura *et al.*, 1967).

PASTEURIZATION

The choice of dose for radiation pasteurization or radurization of fishery products has been governed largely by organoleptic considerations, the highest dose which produces no undesirable changes in the product being employed. Results available indicate that some 30 to 40 species of fish, including the more common commercial species, can be successfully preserved by this method (Dassow and Miyauchi, 1965; Masurovsky, Goldblith and Nickerson, 1963; Power *et al.*, 1964a, 1964b; Ronsivalli, Steinberg and Seagran, 1965). Doses are usually in the range of 0.3 to 0.5 Mrad. The shelf life obtained with such doses is in most cases two to three times that of the unirradiated product (table 1). Some of the greatest shelf life extensions have been achieved with shellfish.

Bacteriologically the effects of irradiating fish at 0.3 Mrad are to kill a large proportion of the bacteria which cause spoilage, that is those of the genus *Pseudomonas*. The flora of fish irradiated at 0.3 Mrad consists chiefly of Gram-positive organisms and members of the *Achromobacter* genus (Shewan and Liston, 1958; Kazanas *et al.*, 1966; Shiflett, Lee and Sinnhuber, 1966; Slavin, Ronsivalli and Connors, 1966). Having extended the shelf life by two or three times, there is a potential danger that the health hazard has been increased, particularly with respect to the spore-forming organisms *Cl. botulinum* and *Cl. welchii*. The spore-forming bacteria are much more resistant to irradiation than the spoilage bacteria, and there is a possible danger of the fish becoming a health hazard before overt spoilage is evident. This will be discussed later, but because of this, the suggestion has been made that lower doses in the region of 0.1 Mrad should be used, with a consequent shorter shelf life but less health hazard.

TABLE 1. SOME DATA ON THE STORAGE LIFE OF IRRADIATED PRODUCTS AT CHILL TEMPERATURES
(from various sources)

Product	*Irradiation dose* (*Mrad*)	*Extension of storage life* (*Days*)	°C (°F)
Haddock	0.75	39–49	0 (32)
Cod	0.25	45	0 (32)
Pacific cod	0.25	56	2 (35)
Pollack	0.25	21	2 (35)
Sole	0.25	35	1 (33)
Sole	0.2–0.3	24–32	1 (33)
Halibut	0.2	25	6 (42)
Halibut	0.2	15	2 (35)
Lobster meat (boiled)	0.25	166	2 (35)
Blue crab (cooked)	0.75	90	1 (33)
King crab meat	0.2	23–28	6 (42)
King crab meat	0.2	7–11	1 (33)
Raw shrimp (shelled)	0.15	10–15	1 (33)
Shrimp (cooked)	0.15	10–15	2 (35)
Clams.(soft shelled)	0.5	119	

PACKAGING

Packaging fish itself offers several advantages (Shewan and Hobbs, 1963; Shewan and Taylor, 1962; Hansen and Jørgensen, 1967). It protects the fish from outside contamination, it inhibits fat oxidation if an oxygen-free atmosphere or vacuum pack is used, and it can provide some extension of shelf life. There are other commercial advantages in packaging: the fish is more easily handled by the shopper and can be made attractive, hence promoting sales. The advantages are governed largely by the choice of packaging materials, and needless to say the better materials are usually the most expensive.

In considering the distribution of irradiated fish, some kind of protective package is necessary, at least as far as retail distribution is concerned. Data is gradually accumulating on which materials are best suited to specific products and processes. In the present case the material must withstand the irradiation process in addition to any other requirements of the product to be packed. Whilst some work still remains to be done it is clear that several materials suitable for packaging fish are available, certainly as far as pasteurizing doses are concerned.

Packaging of fish in an impermeable film sealed under vacuum and irradiated at 0.3 Mrad would offer the greatest extension of shelf life. The shelf life of fish in a vacuum pack is governed by the quality of the fish before packaging, the biggest advantage being obtained with fresh fish. Similarly the best results are obtained with irradiation if the fish is irradiated fresh.

As with all processes that fall short of sterilization, radiation pasteurization cannot be used to cover up bad hygiene, handling and storage. Any commercial utilization of this process must therefore take into account the use of good hygiene and low temperature storage.

HEALTH HAZARD

In the case of sterilization, by definition there would be no microbiological health hazard. As for chemical hazards, there is an increasing amount of evidence to indicate that no real hazard results from the irradiation process, and also that the nutritional value of the fish is not seriously diminished (Hickman, 1966; Raica and Howie, 1966; Whitehair, 1966; Slavin, Ronsivalli and Connors, 1966).

With radiation pasteurization it is possible to specify conditions of treatment, handling and storage of fishery products which would virtually eliminate any health hazard. If such hazards exist, they will therefore be a direct result of handling and storage under conditions which are less than satisfactory. Since this could equally well be said of unirradiated foods, the pertinent question is "Does the irradiation process increase or diminish the potential health hazards?"

With fishery products the main potential hazards are the presence of enteropathogenic organisms such as *Salmonella* in shellfish caught in polluted waters, and type E botulism from fishery products in general. In the

case of shellfish contaminated with *Salmonella* and similar organisms, the available evidence suggests that pasteurizing doses of irradiation would substantially reduce though not eliminate these bacteria (Quinn, Anderson and Dyer, 1967). In this case, therefore, radiation pasteurization would considerably reduce any health hazard, though not necessarily eliminate it.

In the case of spore-forming bacteria, in particular *Cl. botulinum* type E and *Cl. welchii*, the situation is somewhat different. Pasteurizing doses in the region of 0.3 Mrad will only effect a 90 per cent reduction in the numbers of spores present. *Cl. botulinum* type E is the most important spore-forming organism of this type, primarily because of its widespread occurrence in fishery products in many parts of the world (Ando and Inouë, 1957; Dolman, 1960; Dolman and Iida, 1963; Johannsen, 1963, 1965; Craig and Pilcher, 1965; Eklund and Poysky, 1965a; Ward, Carroll and Garrett, 1965; Bott *et al.*, 1965; Cann *et al.*, 1965, 1966; Hobbs *et al.*, 1965). The distribution of this organism in fishery products in their natural environment is such that any consideration of fish processing must assume its presence, at least in some of the fish.

Besides the resistance of its spores, *Cl. botulinum* type E is capable of growth and toxin production at temperatures as low as 4°C (39.2°F) (Dolman *et al.*, 1950; Johannsen, 1961; Schmidt, Lechowich and Folinazzo, 1961).

Results of experiments to determine the rate of growth and toxin production in fish by type E show that it is variable but dependent on level of contamination and species of fish as well as temperature of storage. Some of our own results are given in figs 1 and 2 and table 2. These results do not differ significantly from those obtained by other workers. From these results it is evident that with higher temperatures of incubation, the time required for toxin to appear is not much different from the expected storage life, especially in the case of irradiated fish. At the lower levels of contamination with storage at 5°C (41°F) no toxin was detected over periods much longer than the expected storage life of the products.

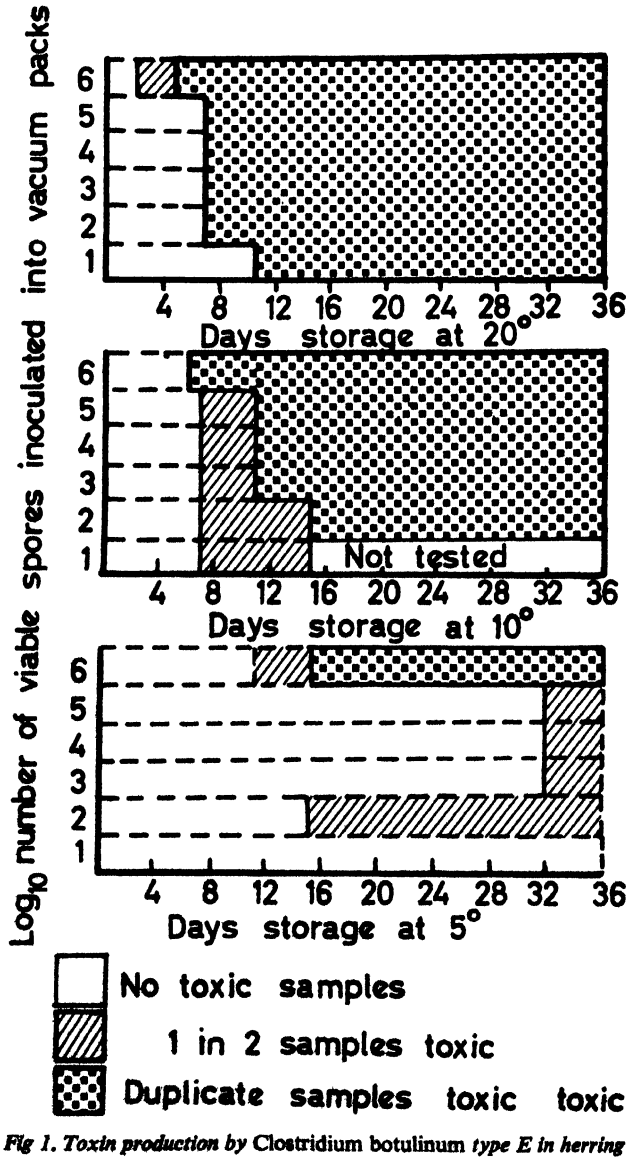


Fig 1. Toxin production by Clostridium botulinum *type E in herring*

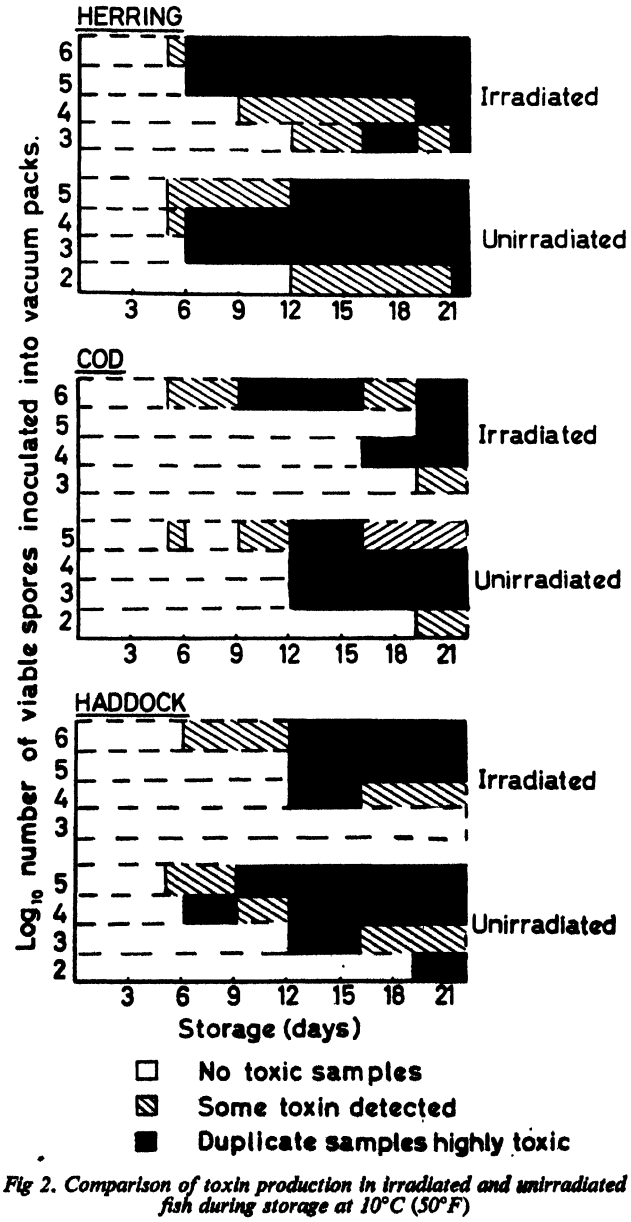


Fig 2. Comparison of toxin production in irradiated and unirradiated fish during storage at 10°C (50°F)

TABLE 2. SOME RELATIONSHIPS BETWEEN ESTIMATED SHELF LIFE OF FISH AND TOXIN PRODUCTION BY *Cl. botulinum* TYPE E (10^5 to 10^7 spores per gram)

	20°C (68°F)		10°C (50°F)		5°C (41°F)	
	Shelf life (*days*)	*Toxin* (*days*)	*Shelf life* (*days*)	*Toxin* (*days*)	*Shelf life* (*days*)	*Toxin* (*days*)
Cod	1		3	5–9	7	
Cod 0.3 Mrad	2		6–9	5–9	12–15	
Haddock	1		3	5–12	7	
Haddock 0.3 Mrad	2		6–9	5–12	12–15	
Herring	<1	1–5	1–2	4–7	3–4	12–32
Herring 0.3 Mrad	1	1–5	2–4	4–7	6–8	12–32
Kipper	5–6	2–8	6–9	8–20	7–10	>28
Kipper 0.3 Mrad	10–15	2–8	10–18	8–20	15–20	>28
Smoked haddock	2–5	3	5–8	28–30	10–12	>28
Smoked haddock 0.3 Mrad	4–8	3–4	10–15	28–30	20–25	28

It is evidently possible to devise conditions under which fish can become toxic before overt spoilage occurs and that radiation pasteurization can increase this hazard. It must be stressed, however, that this hazard exists, albeit to a lesser degree, with unirradiated fish and storage of fish at temperatures of 10° to 20°C (50° to 68°F) should be considered dangerous in any case.

It is important to try and estimate the extent of this hazard in relation to current handling and storage procedures since it is clear that if contamination levels are low and storage temperatures are low the hazard is negligible. Indeed, if the temperature is maintained below 4°C (39.2°F) throughout there is no hazard.

Few data are available to indicate the natural level of contamination, but what there is suggests that it is certainly less than one spore per gram of freshly-caught fish (Nickerson, 1965; Cann *et al.*, 1966). After irradiation of 0.3 Mrad this would be reduced to less than 1 spore per 10 g of fish. From the data available it is evident that provided the fish is stored below 10°C (50°F) there is a considerable safety margin between spoilage and toxin production with this level of contamination.

If we had to consider only the contamination level of freshly caught fish, there would appear to be little, if any, hazard. If, however, fish with a low level of contamination is being processed continuously in a factory, there exists the possibility of a build-up of contamination in the factory itself. No data is available on this point except that experience with spoilage bacteria would suggest that this could in fact be a real danger and that fish could leave such a factory with much higher contamination levels than the freshly-caught fish.

The main conclusions to be drawn regarding type E botulism are that provided the storage temperature of fish can be maintained below 5°C (41°F) until it is consumed, there is little, if any, danger of accumulation of toxin before the fish has reached an advanced state of spoilage. It is perhaps unfortunate that in current practice this cannot be assumed. The most difficult point at which to apply any kind of control is at the end of the distribution chain, after the fish has been purchased by the consumer. At least one of the recent outbreaks in the United States appears to have resulted from mishandling at precisely this point. Radiation pasteurization could result in an increase of this hazard, but only under extreme conditions of a high level of contamination and a high storage temperature. It certainly does not diminish the hazard.

Whilst type E is undoubtedly the most important health hazard, types B and F *Cl. botulinum* have been isolated from fishery products or the marine environment (Craig and Pilcher, 1965; Eklund and Poysky, 1965b; Hobbs *et al.*, unpublished data; Dolman *et al.*, 1960; Johannsen, 1963). Also, *Cl. welchii* has been isolated from fresh and processed fish (Hobbs *et al.*, 1965; and unpublished data).

The radiation resistance of all these organisms is higher than that of type E (Roberts and Ingram, 1965), and whilst type E could be eliminated from fish by irradiation at 2.0 to 2.5 Mrad, types B and F and *Cl. welchii* spores would require much higher doses. All the work on radiation pasteurization has so far been carried out using type E; it would be interesting to see what the effects of this treatment would be on growth and toxin production by these other organisms, particularly in view of the low temperature growth and toxin production by *Cl. botulinum* type F reported by Walls (1965).

COMMERCIAL EXPLOITATION

It is evident that sterilization of fishery products by irradiation is not commercially feasible at the moment, hence any commercial exploitation must be of radiation pasteurized products. The two main questions are how feasible is the process technologically, and how will it compete both technologically and commercially with the established processes such as drying, salting, canning, chilling and freezing? The answers to these questions will depend to some extent on the stage of development of these various processes in different countries.

Among the advantages claimed for fish irradiation are expansion of marketing area, improvement of quality, reduction of spoilage losses, facilitation of distribution and reduction of transport and handling costs.

In Great Britain the industry relies to a very large extent on icing for preservation of fish. During the last six years the total quantity of fish landed has been in the region of 800,000 t per year. About half of this comes from near and middle waters and reaches the consumer in a relatively fresh state two to 12 days after catching. In the case of distant water fish, accounting for the other half, the vessels are making round trips averaging about 21 days. This means that the freshest fish landed from these vessels is about five days in ice and the oldest fish about 15 days in ice. It reaches the consumer about one to three days after this. Ice when used to its best advantage will keep fish such as cod and haddock, the main commercial species landed from distant water trawlers, in edible condition for only 17 days.

Surveys of the distribution chain on land in the United Kingdom have shown that serious losses in quality, mainly due to high temperatures, were occurring between discharge of the vessels and being sold over the counter.

Several methods for improving the quality of fish have been examined. The only one being applied at the moment is freezing at sea. There has been a steady increase in freezing of fish at sea over the last few years, and landings of sea-frozen fish in the United Kingdom now account for something over 10 per cent of the distant water landings. This will undoubtedly increase substantially in the near future. Exploitation of irradiation at sea could therefore effect a big improvement of the quality of fish, including retailed frozen fish, since most of this is landed in ice and frozen on shore. Irradiation soon after the fish is caught would secure the maximum advantage of this process. For this reason, the results of the United States' experiments with an irradiator on board ship are awaited with interest.

In spite of the increasing popularity of frozen fish, there is still a considerable demand for wet fish, and there is every indication that this situation will continue. At the moment about half of the sea-frozen fish landed in the United Kingdom is thawed out and retailed as "fresh sea-frozen" fish.

To maintain the market for wet fish, a high level of quality must be achieved. It is perhaps in retail marketing that radiation pasteurization could best be applied. One of the few commodities lacking in most supermarkets is fresh fish, and efforts are being made to retail fish in this way in the United Kingdom at the moment. It is envisaged that blocks of sea-frozen, whole gutted fish such as cod, held as they are now in cold stores at the ports, would be defrosted, filleted and cut into suitable consumer sizes, packaged and dispatched to the supermarkets. At the moment a period of four days is anticipated for processing, distribution and sale, in order to present the consumer with top quality fish. Radiation pasteurization could provide the distributors and retailers with extra storage time, say six to eight days, without any loss in quality. This would enable them to overcome day-to-day market fluctuations with less wastage. A necessary condition of this system would be maintenance of the temperature below 4°C (39.2°F) throughout the distribution chain. This is important whether the fish is irradiated or not, and is in fact being adhered to in the current marketing trials.

As regards cost, it has been estimated that a plant working 24 h a day, seven days a week, 50 weeks a year, irradiating fish at 0.3 Mrad with an annual throughput of 2,000 t would add about ¾d/lb to the cost of the packaged fish. This estimate includes buildings, plant overheads, depreciation, etc. At 8,000 t per year, the cost would be less than ½d/lb (Rhodes, 1964). At least in some of our major fishing ports these quantities of fish would be available for irradiation.

FISH MEAL

Decontamination of fish meal by irradiation is another possible area of application. The particular problem is the elimination of enteropathogenic bacteria, chiefly *Salmonella*. Fairly extensive studies in the United Kingdom of the bacteriology of fish meal production almost invariably failed to find any *Salmonella*. On the other hand fish meals imported into the United Kingdom regularly show levels of contamination up to 10^8/g (Anon., 1959; 1961). Some outbreaks of food poisoning have in fact been traced to cattle fed on such contaminated meals (Handloser, 1956; Rohde and Bischoff, 1956).

Fish meal differs from wet fish in that the growth of bacteria in the dried meal is not a problem since they occur in a medium with a water activity of the order of 0.45 (Mossel and de Groot, 1965), which does not permit their growth. Organisms such as *Salmonella* would not survive the manufacturing process, hence their occurrence in meals is due to post-process recontamination. This has been confirmed experimentally in some cases (Rutquist, 1961; Schaaf, 1962; Clise and Swecker, 1965; Magwood, Fung and Byrne, 1965; Mossel, 1966). Improvements in sanitation might therefore be expected to lead to *Salmonella*-free meals; this again has been demonstrated (Engel and Mossel, 1965, 1966). Where this cannot be achieved, radiation decontamination is an attractive possibility. The bagged product requires irradiation at a dose level of about 0.6 Mrad. Doses such as this would cause no loss of nutritive value and the process is therefore one of the simplest and most promising ways of decontaminating fish meals (Mossel and de Groot, 1965). Whether the decontamination should be carried out in the country of origin or in the importing country is open to argument. For practical reasons, however, terminal treatment of mixed feeds is probably the best procedure (Mossel, 1967). In either case irradiation could be used, though pelleting with steam appears just as effective and in fact simpler (Mossel, 1967).

CONCLUSIONS

Radiation preservation of fishery products has potential advantages over other methods, chiefly in terms of handling and distribution. At the moment, any commercial exploitation must be of radiation pasteurized or radurized products. In countries such as the United Kingdom with a well-established cold chain for distribution and sale of fishery products it has to compete with frozen fish. There are, however, areas where radiation pasteurized fish may find a place, for example in the marketing of packaged unfrozen fish and fishery products. This depends on the continued existence of a market for chilled fresh fish as opposed to frozen fish, and there is every indication that this situation will persist certainly for many years.

A promising practical application is the decontamination of imported fish meals.

Irradiation would become a more practical proposition if some means could be evolved for eliminating the microbiological hazards completely. A sterile product retaining the natural organoleptic properties of the fresh fish could be a serious competitor to frozen and canned fishery products.

References

ANDO, Y and INOUË, K Studies on growth and toxin production of *Clostridium botulinum* type E in fish products. *Bull. Jap. Soc. scient. Fish.*, **23**(7), 8.
1957

ANDERSON, A W, CORLETT, D A and KRABBENHOFT, K L The effects of additives on radiation-resistance of *Cl. botulinum* in meat. In *Microbiological Problems in Food Preservation by Irradiation*, IAEA, Vienna, pp. 87–97.
1967

ANON. *Salmonella* organisms in animal feeding stuffs and fertilizers. *Mon. Bull. Minist. Hlth*, HMSO, London, **18**, 26.
1959

ANON. *Salmonella* organisms in animal feeding stuffs. *Mon. Bull. Minist. Hlth*, HMSO, London, **20**, 73.
1961

BOTT, T L, DEFFNER, J S, MCCOY, E and FOSTER, E M Occurrence of *Clostridium botulinum* type E in fish of the Great Lakes. *Bact. Proc.*, p. 1.
1965

CANN, D C, WILSON, B B, HOBBS, G, SHEWAN, J M and JOHANNSEN, A The incidence of *Clostridium botulinum* type E in fish and bottom deposits in the North Sea and off the coast of Scandinavia. *J. appl. Bact.*, **28**, 426.
1965

CANN, D C, WILSON, B B, SHEWAN, J M and HOBBS, G The incidence of *Clostridium botulinum* type E in fish products in the United Kingdom. *Nature, Lond.*, **211**, 205.
1966

CLISE, J D and SWECKER, E E *Salmonellae* from animal by-products. *Publ. Hlth Rep., Wash.*, **80**, 899.
1965

CRAIG, J M and PILCHER, K S Ecological survey of *Clostridium botulinum* type E in the Pacific Northwest. *Bact. Proc.*, p. 1.
1965

DASSOW, J A and MIYAUCHI, D T Radiation preservation of fish and shellfish of the North-east Pacific and Gulf of Mexico. Radiation preservation of foods. Publ. 1273, Nat. Acad. Sci., N.R.C., Washington, D.C.
1965

DOLMAN, C E Type E Botulism: a hazard of the North. *Arctic*, **13**, 4.
1960

DOLMAN, C E, CHANG, H, KERR, D E and SHEARER, A R Fish borne and type E botulism. *Can. J. publ. Hlth*, **46**, 135.
1950

DOLMAN, C E and IIDA, H Type E botulism; its epidemiology, prevention and specific treatment. *Can. J. publ. Hlth*, **54**, 293.
1963

DOLMAN, C E, TOMSICH, M, CAMPBELL, C C R and LAING, W B Fish eggs as a cause of human botulism. *J. infect. Dis.*, **106**, 5.
1960

EKLUND, M W and POYSKY, F T The significance of *Clostridium botulinum* type E in the application of radiation-pasteurization process to Pacific crab meat and flounder. Radiation pasteurization of foods. U.S. Atomic Energy Commission, Fifth Annual Contractors' Meeting, p. 73.
1965a

EKLUND, M W and POYSKY, F T *Clostridium botulinum* type F from marine sediments. *Science, N.Y.*, **149**, 306.
1965b

ENGEL, C and MOSSELL, D A A Onderzoekingen naar de bruto-en netto-decontaminatiewaarde van mengvoedercomponenten, uitevoerd in opdracht van het Produitschap voor Veevoeder. *Reports, Central Institute for Nutrition Research*, No. 1891.
1965

ENGEL, C and MOSSEL, D A A *Ibid.*, No. 2135.
1966

FARKAS, J, KISS, I and ANDRÁSSY, E Reduction of radiation dose requirements of foods by additives. In *Microbiological Problems in Food Preservation by Irradiation*, IAEA, Vienna, pp. 123–131.
1967

HANDLOSER, H M Epidemiologische Bedeutung salmonella-infizierter Tierfuttermittel (insbesondere Kochenschort und Fischmehl) als Quelle verschiedener Lebensmittelvergiftungen. *Zentbl. Bakt. ParasitKde*, Abt. I Ref. **159**, 149.
1956

HANSEN, P and JØRGENSEN, B V The effect of ionizing radiation and antioxidant treatment on the quality and storage life of vacuum packed trout at 0°C. In *Microbiological Problems in Food Preservation by Irradiation*, IAEA, Vienna, pp. 133–138.
1967

HICKMAN, J R United Kingdom Food Irradiation Programme —wholesomeness aspects. In *Proceedings of the International Symposium on Food Irradiation*, IAEA, Vienna, p. 101.
1966

HOBBS, G, CANN, D C, WILSON, B B and SHEWAN, J M The incidence of organisms of the genus *Clostridium* in vacuum packed fish in the United Kingdom. *J. appl. Bact.*, **28**, 265.
1965

JOHANNSEN, A Environmental conditions for the growth and toxin formation of *Clostridium botulinum*, with particular reference to the behaviour in vacuum packed foods. Svenska Institutet för Konserveringsforskning, Göteborg, Sweden, Report No. 100.
1961

JOHANNSEN, A *Clostridium botulinum* in Sweden and adjacent waters. *J. appl. Bact.*, **26**, 43.
1963

JOHANNSEN, A *Clostridium botulinum* type E in foods and the invironment generally. *J. appl. Bact.*, **28**, 90.
1965

KAZANAS, N, EMMERSON, J A, SEAGRAN, H L and KEMPE, L L Effect of gamma irradiation on the microflora of freshwater fish. *Appl. Microbiol.*, **14**, 261.
1966

MAGWOOD, S E, FUNG, J and BYRNE, J L *Studies on Salmonella* contamination of environment and product of rendering plants. *Avian Dis.*, **9**, 302.
1965

MASUROVSKY, E B, GOLDBLITH, S A and NICKERSON, J T R Effects of sub-sterilization doses of ^{60}Co gamma irradiation on the cold storage life extension of shucked soft-shelled clams and haddock fillets. *Appl. Micro biol.*, **11**, 220.
1963

MIURA, T, SAKAGUCHI, S, SAKAGUCHI, G and MIYAKI, K 1967 Radiosensitivity of type E botulinus toxin and its protection by proteins, nucleic acids and some related substances. In *Microbiological Problems in Food Preservation by Irradiation*, IAEA, Vienna, pp. 45–54.

MOSSELL, D A A 1966 Perspectives for the use of ionizing radiation in the decontamination (*Salmonella* radicidation) of some frozen proteinaceous foods and dried mixed feed ingredients. *Proceedings of the International Symposium on Food Irradiation*, IAEA, Vienna, p. 365.

MOSSEL, D A A 1967 *Salmonella* radicidation of dry mixed feeds and feed ingredients. In *Microbiological Problems in Food Preservation by Irradiation*, IAEA, Vienna, pp. 15–25.

MOSSEL, D A A and DE GROOT, A P 1965 The use of pasteurizing doses of gamma radiation for the destruction of *Salmonella* and other *Enterobacteriaceae* in some foods of low water activity. Radiation preservation of foods. *Proc. Int. Conf.*, Boston, Mass., 1964, *Publ.* 1273 *Nat. Acad. Sci.*, N.R.C., Washington, D.C.

NEWELL, K W, MCCLARIN, R, MURDOCK, C R, MACDONALD, W N and HUTCHINSON, H L 1959 Salmonellosis in Northern Ireland with special reference to pigs and *Salmonella*-contaminated pig meal. *J. Hyg., Camb.*, **57**, 92.

NICKERSON, J T R 1965 The effect of gamma rays on haddock and clams inoculated with *Clostridium botulinum* type E. Radiation pasteurization of foods. U.S. Atomic Energy Commission, Fifth Annual Contractors' Meeting, p. 107.

POWER, H E, FRASER, D I, DYER, W J and CASTELL, C H 1964a Gamma irradiation as a means of extending the storage life of haddock fillets. *J. Fish. Res. Bd Can.*, **21**(4), 827.

POWER, H E, FRASER, D I, NEAL, W, DYER, W J, CASTELL, C H, FREEMAN, H C and IDLER, D R 1964b Use of gamma radiation for the preservation of scallop meat. *Ibid.*, **21**, 813.

QUINN, DOROTHY J, ANDERSON, A W and DYER, J F 1967 The inactivation of infection and intoxication microorganisms by irradiation in seafood. In *Microbiological Problems in Food Preservation by Irradiation*, IAEA, Vienna, pp. 1–13.

RAICA, N and HOWIE, D L 1966 Review of the United States Army wholesomeness of irradiated food program. *Proceedings of the International Symposium on Food Irradiation*, IAEA, Vienna, p. 365.

RHODES, D N 1964 Pasteurization of fish by ionizing radiation; a study of feasibility in the United Kingdom. *Fd Irrad.*, **4**, 4 A8.

ROBERTS, T A 1967 Effects of heating and gamma radiation on the inhibition of bacterial spores by curing agents. In *Microbiological Problems in Food Preservation by Irradiation*, IAEA, Vienna, pp. 115–121.

ROBERTS, T A and INGRAM, M 1965 Radiation resistance of spores of Clostridium spores in aqueous suspension. *J. Fd Sci.*, **30**, 879.

ROHDE, R and BISCHOFF, J 1956 Die epidemiologische Bedentung salmonellain-fizierter Tierfuttermittel (insbesondere Kochenschort und Fischmehl) als Quelle verschiedener Lebensmittelvergiftungen. *Zentbl. Bakt. ParasitKde*, Abt. I, Ref. 159, 149.

RONSIVALLI, L T, STEINBERG, M A and SEAGRAN, H L 1965 Radiation preservation of fish of the North-West Atlantic and the Great Lakes. Radiation preservation of foods. *Publ.* 1273, *Nat. Acad. Sci.*, N.R.C., Washington, D.C.

RUTQUIST, L 1961 Vorkommen von *Salmonella* in Futtermitteln vegetabilischen Ursprunges. *Zentbl. VetMed.*, **8**, 1016.

SCHAAF, A VAN DER 1962 Salmonellose onder de werking van de Veewet. *Tijdschr. Diergeneesk.*, **87**, 976.

SCHMIDT, C F, LECHOWICH, R V and FOLINAZZO, J F 1961 Growth and toxin production of type E *Clostridium botulinum* below 40°F. *J. Fd Sci.*, **26**, 626.

SHEWAN, J M 1966 Present status and future prospects of irradiation preservation of fish. *Proceedings of the International Symposium of Food Irradiation*, IAEA, Vienna, p. 489.

SHEWAN, J M and HOBBS, G 1963 Prepackaging unfrozen fish. *Fishg News int.*, **2**(1), 103.

SHEWAN, J M and LISTON, J 1958 Experiments on the irradiation of fish with 4 MeV cathode rays and ^{60}Co gamma rays. *Proc. II U.N. Int. Conf.*, PUAE 27, 377.

SHEWAN, J M and TAYLOR, A A 1962 The packaging of wet and smoked fish; some problems and future prospects. *Inst. Packaging Conference Guide*, HMSO, London.

SHIFLETT, M A, LEE, J S and SINNHUBER, R O 1966 Microbial flora of irradiated Dungeness crab meat and Pacific oysters. *Appl. Microbiol.*, **14**, 411.

SLAVIN, J W, RONSIVALLI, L J and CONNORS, T J 1966 Status of research and developmental studies on radiation pasteurization of fish and shellfish in the United States. *Proceedings of the International Symposium on Food Irradiation*, IAEA, Vienna.

WALLS, N W 1965 Physiological studies on *Clostridium botulinum* type F. Radiation pasteurization of foods. U.S. Atomic Energy Commission, Fifth Annual Contractors' Meeting, 1965, p. 81.

WARD, B Q, CARROLL, B J and GARRETT, E S 1965 Study of *Clostridium botulinum* type E. Radiation pasteurization of foods. U.S. Atomic Energy Commission, Fifth Annual Contractors' Meeting, 1965, p. 124.

WHITEHAIR, L A 1966 Wholesomeness and public health research in the United States Atomic Energy Commission food irradiation programme. *Proceedings of the International Symposium on Food Irradiation*, IAEA, Vienna.

Irradiación de Productos de la Pesca—Posibilidades Españolas

por D. de la Sierra Serrano

Irradiación de productos de la pesca—posibilidades españolas

En este trabajo se presentan las posibilidades de la irradiación como método de conservación de los productos de la pesca en España de acuerdo con la experiencia internacional.

Se describen las condiciones favorables existentes en el país para la realización de un Plan Nacional de Irradiación de productos de la pesca y, por último, se trazan los rasgos generales de sus distintas etapas aplicativas.

Irradiation of fish products—Spanish possibilities

The possibilities of using irradiation as a preservation method for seafood in Spain are reviewed in the knowledge of international experience.

The favourable conditions which exist for the implementation of a National Plan for Seafood Irradiation are stressed and the stages that have to be followed are outlined.

Irradiation des produits de la pêche—possibilités espagnoles

Le présent rapport étudie les possibilités d'utilisation de l'irradiation pour la conservation des produits de la mer en Espagne, compte tenu de l'expérience internationale.

Les conditions favorables à l'adoption d'un Plan national d'irradiation des produits de la mer y sont examinées, ainsi que les étapes indispensables à sa mise en oeuvre.

LOS productos de la pesca constituyen actualmente uno de los factores básicos de la alimentación humana.

No obstante, su consumo per capita es muy variado dentro de los países pesqueros y a veces muy reducido.

Debido al aumento y modernización de la flota pesquera, principalmente de los barcos congeladores, el consumo per capita en España ha mejorado considerablemente en los últimos años. Sin embargo, si tenemos en cuenta que la necesidad de consumo de proteínas del pescado por persona y día es de 12 g (100 g de pescado fresco), se precisarían alrededor de un millón de toneladas destinadas al consumo en fresco.

En España se destina, como en otros muchos países, más del 50 por ciento de la producción pesquera a la industrialización, comprendiendo ésta no sólo la conserva enlatada, sino también las salazones y la fabricación de harinas de pescado y aceites.

La mayor parte del pescado fresco es sometido a la preservación mediante temperaturas de refrigeración y, en menor cantidad pero con tendencia a aumentar, se conserva por congelación.

En nuestro país, los métodos de preservación del pescado por refrigeración han recibido un alentador impulso en los últimos años, mientras que las conservas tradicionales españolas que tante fama merecieron en el pasado, se hallan en regresión, no utilizándose en la actualidad más que el 20 por ciento de su capacidad total de producción.

La gran riqueza que para la economía española supone la industria conservera de pesca—2.3 millones de pesetas (378.000 dólares) de beneficio anual—merece una atención cuidadosa con el fin de aprovechar al máximo sus posibilidades productivas y de exportación.

Es de destacar, además, la enorme importancia económica de las salazones, de bacalao especialmente, que superan en volumen a las restantes conservas del pescado con un total de 80.000 t anuales, mientras que las conservas enlatadas de atún, los escómbridos y las sardinas, suman 55.000 t.

La conservación por irradiación puede desempeñar un papel de primordial importancia en la modernización y amplio desarrollo de esta industria, facilitando el abastecimiento más regular de pescado para industrializar y la comercialización de sus productos en mejores condiciones. Los recientes e importantes avances en el campo de la irradiación del pescado y otros productos de la pesca, son altamente prometedores.

Aún no se ha autorizado en ningún país el consumo de pescado conservado por irradiación, pero todo parece indicar que entramos en el umbral de la comercialización.

Los países que más se han ocupado de la applicación del nuevo método son: Estados Unidos, U.R.S.S., Inglaterra, Francia y Canadá.

POSIBILIDADES ESPAÑOLAS

España, país tradicionalmente pesquero, que ocupa el sexto lugar en el mundo por el volumen de sus capturas, con una población muy habituada al consumo de pescado, reúne además un conjunto de condiciones sumamente favorables para aplicar un Plan Nacional de Irradiación de Productos de la Pesca, de forma escalonada. Entre las ventajas que pueden facilitar su ejecución figuran las siguientes:

(1) Longitud de sus costas.
(2) Gran variedad de especies.
(3) Concentración de la pesca en pocos puertos.

Además de estas ventajas, la necesidad de abastecimiento a zonas interiores y el clima cálido la mayor parte del año, son factores que aconsejan la introducción del nuevo método.

En general, su aplicación se efectuaría, como en otros países, asociando el nuevo método a otros tradicionales:

—El tratamiento mixto de dosis de radurización con temperaturas de refrigeración aumentaría el tiempo de conservación del pescado fresco en tres o cuatro veces el período normal. Serían suficientes dosis de 250 a 500 krad.

—La radapertización del pescado elaborado, una vez enlatado, a dosis del orden de 4,5 Mrad puede sustituir la esterilización por el calor.

—La irradiación del pescado en unión de la congelación, evita tener que aplicar temperaturas muy bajas, aumentando la eficacia de la conservación sobre todo después de la descongelación.

—En los productos derivados tales como las harinas de pescado destinadas al consumo de la ganadería, etc., dosis relativamente bajas (de 350 a 650 krad) producen la radicidación (descontaminación) de *Salmonella*, contribuyendo a resolver un importante problema de higiene pecuaria y de salud pública.

La expansión comercial del pescado quedaría favorecida por las siguientes razones:

(1) Apertura de nuevos mercados, principalmente en zonas interiores donde actualmente no llega el pescado fresco en buenas condiciones.
(2) Mayor variedad en la dieta con más garantía higiénica.
(3) Incremento de muchos tipos de pescado en el mercado nacional e internacional.
(4) Regulación del mercado, permitiendo acopio de existencias en épocas de escasez.

PROGRAMA DE TRABAJO PARA EL DESARROLLO DE UN PLAN NACIONAL DE IRRADIACION DE PRODUCTOS DE LA PESCA

Utilizando la experiencia internacional y teniendo en cuenta las condiciones y posibilidades españolas, podría iniciarse un programa en nuestro país que comprendiera el estudio de la irradiación de las principales especies de pescado, crustáceos y moluscos, así como la radicidación de las harinas de pescado.

El plan de trabajo debería comprender tres fases principales:

(1) Estudio de la tecnología y control sanitario de los productos de la pesca en fase experimental.
(2) Irradiación de muestras con unidades piloto semiindustriales para poner a punto las técnicas a utilizar y adiestrar los especialistas industriales.
(3) Construcción y funcionamiento de unidades de irradiación en escala comercial en los principales puertos pesqueros españoles (Vigo, Coruña y puertos cantábricos) después de conseguir las autorizaciones correspondientes para el consumo público.

Dentro de cada una de estas fases, se pueden considerar los apartados siguientes:

(a) Especies españolas y dosis
(b) Pruebas microbiológicas
(c) Ensayos físico-químicos
(d) Contrastación biológica
(e) Pruebas organolépticas de aceptabilidad.

Especies españolas y dosis

Las especies capturadas por la flota pesquera española por orden de mayor importancia son: (1) bacalao (*Gadus morhua*) y merluza (*Merluccius merluccius*); (2) sardina (*Sardina pilchardus*) y anchoa (*Engraulis encrasicholus*); (3) lubina (*Morone* sp.), congrio (*Conger conger*), etc. y (4) moluscos y crustáceos. Las especies más selectas por su valor económico y calidad, como la merluza y pescadilla, bacalao, moluscos y crustáceos, han resultado ser, en principio, las más indicadas para el tratamiento por irradiación.

Las dosis varían con las especies ya que no todas presentan la misma reacción ante las radiaciones ionizantes, siendo por tanto distintos también los efectos.

Dentro de una misma especie, la aplicación de la dosis dependerá:

(1) Finalidad (radurización, radicidación o apertización).
(2) Grado de contaminación del pescado.

Para cada especie y tipo de irradiación, la dosis es función:

(1) Del número inicial de gérmenes viables (grado de contaminación inicial).
(2) Del grado final de contaminación tolerable (número de gérmenes viables después de la irradiación).

La relación entre estos dos factores nos da el *factor de inactivación* y por consiguiente la dosis recomendable.

El problema de elección de la dosis más adecuada, está planteado, por otra parte, entre dos parámetros opuestos: por un lado la necesidad de destruir las bacterias y microorganismos en general y, por otro, prevenir los efectos perjudiciales (olores, sabores y otros caracteres organolépticos anormales), que pueden sobrevenir cuando las dosis son elevadas.

Pruebas microbiológicas

Los gérmenes que constituyen la flora microbiana del pescado son los responsables exógenos de su alteración siendo los agentes endógenos (enzimas) los que cooperan en la destrucción de las sustancias orgánicas. Por ser la eliminación o inhibición de dicha microflora el objetivo perseguido por todos los métodos de conservación, en la irradiación de alimentos las pruebas de control microbiológico tienen una importancia fundamental.

En nuestro país, un programa de irradiación de los productos de la pesca tendría que afrontar con todo interés los aspectos microbiológicos indicados, comprendiendo el estudio de la destrucción de los gérmenes banales-saprofitos responsables de la alteración y el problema de la supervivencia en la flora residual de gérmenes patógenos.

Microflora del pescado y mariscos. Las bacterias que contiene el pescado son las mismas del medio ambiente que le rodea.

La importancia numérica de la microflora y las facilidades de proliferación, están determinadas en muy considerable parte por dos circunstancias esenciales: (1) naturaleza proteolítica y (2) condiciones de temperatura, que pueden provocar una selección de especies microbianas.

La microflora de los moluscos y crustáceos es muy análoga a la de los peces, presentando alguna variación que depende de las condiciones ecológicas y proximidad a la costa, sobre todo en los moluscos gasterópodos y lamelibranquios, cuya contaminación debe ser evaluada por el número de *E. coli* y no do los coliformes, como en otros productos, ya que la primera determinación es mucho más significativa.

El pescado después de capturado puede contener no sólo los gérmenes propios de la contaminación natural, sino también los de la contaminación artificial procedente de las manipulaciones, estimándose que los gérmenes patógenos que puede albergar son: *C. botulinico* (principalmente en los países nórdicos), *Bacillus cereus*, *Clostridium perfringens*, *Salmonella* y *Micrococci* catalasa positivas.

Valoración de la seguridad microbiológica. La destrucción de los gérmenes del pescado por irradiación no se puede limitar a reducir el número para evitar su alteración, sino que debe asegurar que en la flora residual no existan gérmenes patógenos, capaces de proliferar y producir infección o intoxicación. Este problema surge cuando las dosis de irradiación se administran con fines de radurización o radicidación (Rhodes, 1963).

La dosis de irradiación esterilizante (en la literatura especializada actualmente se la denomina *radapertización*), es hallada experimentalmente en analogía con el procedimiento térmico (CIECAI, 1966 y IAEA/FAO/OMS, 1964).

Los métodos empleados para comprobar prácticamente la seguridad microbiológica de los pescados irradiados son muy semejantes a los empleados para el tratamiento térmico, es decir: (a) Ensayos de incubación de los productos (suele ser suficiente en el caso de *C. botulinium*); (b) investigación de *Enterobacteriaceae* patógenas, si se trata de eliminación de *Salmonella*; (c) caracteres organolépticos; (d) recuentos de gérmenes.

Cuando se efectúan tratamientos de radurización o radicidación es muy importante tener en cuenta la temperatura de almacenamiento a que debe estar sometido el pescado fresco después de irradiado. El almacenamiento postirradiación tiene que ser efectuado a temperaturas de refrigeración no superiores a 3°C (37°F) y en el caso de que tenga que conservarse a temperaturas más elevadas, el tiempo de almacenamiento no debe prolongarse más de 12–15 días. Las harinas de pescado en las que se ha efectuado la radicidación, por no ser productos frescos perecederos, no necesitan ninguna de estas precauciones, conservándose en sus envases durante varios meses.

Otros aspectos microbiológicos. Con el tratamiento de la irradiación han surgido nuevos problemas entre los que se pueden citar los siguientes:

(1) *Toxinas bacterianas.* Es muy importante el estado higiénico en que se encuentre el pescado antes de la irradiación, ya que si no está en buenas condiciones puede contener toxinas bacterianas procedentes de la contaminación por gérmenes toxígenos. La irradiación no destruye las toxinas como puede hacerlo el calor, por lo menos a las dosis corrientemente empleadas. Debe exigirse por tanto que los productos hayan sido almacenados convenientemente (IAEA/FAO/OMS, 1964).

(2) *Inducción de gérmenes radiorresistentes.* Se ha observado experimentalmente que repetidas radioexposiciones en determinados gérmenes pueden ocasionar la aparición de poblaciones bacterianas más radiorresistentes que las anteriores. Este problema hay que tenerlo en cuenta sobre todo cuando se aplican dosis que no destruyen toda la microflora. Conviene por tanto, a fin de reducir al mínimo este inconveniente, suprimir la reiterada exposición y sustitución por una sola aplicación cuando se sospeche o compruebe dicha anomalía.

(3) La prevención de la recontaminación por gérmenes se debe conseguir introduciendo el producto en envases resistentes a los efectos de la irradiación, manipulaciones y almacenamiento. Actualmente existen materiales apropiados y económicos (plásticos, etc.) que cumplen bien dichos requisitos.

Métodos de control microbiológico de los alimentos irradiados. Las técnicas empleadas para el examen microbiológico de los alimentos irradiados no difieren en lo esencial, de las aplicadas a los alimentos sin irradiar. En los diferentes países, los métodos se adaptan a las preferencias de los investigadores (Buttiaux, 1966).

El informe del Comité Mixto de expertos de la IAEA/FAO/OMS (1964) recomienda que se deben adoptar métodos unificados internacionales para estos exámenes, con objeto de que al ser aplicados a todos los países, puedan tener un valor significativo y comparable de una nación a otra.

Ensayos físico-químicos

Los efectos que experimenta el pescado como consecuencia de la irradiación pueden ser detectados además por métodos físico-químicos. La evolución físico-química del pescado guarda estrecha relación con el desarrollo de la flora bacteriana y la autolisis enzimática. Por ello el estado del pescado conservado después de la irradiación puede ser controlado mediante valoraciones como las de:

(1) Nitrógeno básico volátil total (NBVT).
(2) Método del ácido tiobarbitúrico (ATB).
(3) Colores de reflexión.

Contractación biológica

Todos los ensayos hasta ahora efectuados con los alimentos irradiados han resultado satisfactorios: los alimentos sometidos al tratamiento por irradiación a muy diversas dosis, no contienen sustancias tóxicas, no cancerígenas, ni inducen radiactividad, no afectando tampoco a la descendencia. No obstante, se considera conveniente continuar las pruebas ateniéndose a normas de experimentación bien definidas.

El Comité Mixto de IAEA/FAO/OMS (1964) recomienda planes de experimentación en varias especies animales de corta y larga duración, debiéndose efectuar análisis sistemáticos hematológicos, bioquímicos e hispatológicos.

Pruebas organolépticas de aceptabilidad

Los posibles cambios organolépticos, debidos a la irradiación, cambios de olor, sabor, color, aspecto, etc., se pueden comprobar mediante paneles formados por personal voluntario.

Para lograr el éxito en la irradiación de productos de la pesca, tendría que cumplirse rigurosamente el programa general delineado. Por tratarse de unos problemas y técnicas completamente nuevos, se requiere una adecuada preparación de los diferentes estratos profesionales capaz de vencer toda clase de obstáculos. Con la fuerza de los hechos en cada etapa, se demostrarán las ventajas positivas de la irradiación del pescado, haciéndole alcanzar una expansión comercial que los procedimientos clásicos de conservación no podrían conseguir.

CONCLUSIONES

De todo lo anteriormente expuesto pueden deducirse las siguientes conclusiones:

(1) La experiencia internacional ha demostrado suficientemente que:

(a) los procedimientos tradicionales de preservación pueden ser mejorados considerablemente con el empleo de la irradiación en dosis apropiadas;

(b) ninguno de los artículos sometidos en condiciones adecuadas al tratamiento por irradiación, presenta alteraciones del olor, sabor, ni de otros caracteres organolépticos;

(c) las pruebas de comestibilidad en animales de experimentación han probado que los productos irradiados no presentan sustancias tóxicas, cancerígenas ni radiactividad inducida.

(2) En España, por sus condiciones ecológicas, geográficas y sociales, la conservación del pescado y mariscos por irradiación ofrece ventajas positivas de orden económico, sanitario y comercial.

(3) La aplicación en nuestro país de un Plan Nacional de Irradiación de los productos de la pesca podría realizarse escalonadamente, concediendo importancia destacada a las pruebas de control microbiológicas, físico-químicas y biológicas, con el fin de garantizar la inocuidad de los productos tratados.

Agradecimiento

Este trabajo ha sido llevado a cabo gracias al entusiasmo, orientación y facilidades dados en la Junta de Energía Nuclear (Madrid, España), por el Sr. Jefe de la Sección de Isótopos, Dr. Del Val Cob y sus colaboradores: Dr. Ortin Sufier y Sr. Fornas Izquierdo.

Hay que expresar también gratitud al Sr. P. Vidal, Presidente Director General de la "Société Conservatome" y a los Sres. F. Rondeney y R. Pierlas, de la misma Sociedad, por las valiosas fuentes bibliográficas de la última fase del trabajo.

References

BANLIEU, J 1963 Conservas de carne y pescado. 2ª edición, Editorial Sintes, Barcelona.

BUTTIAUX, R 1966 *Techniques Bacteriologiques*. Editorial Medical Flammarion, Paris.

COMISIÓN INTERMINISTERIAL ESPAÑOLA DE LA CONSERVACIÓN DE ALIMENTOS POR IRRADIACIÓN 1966 Proyecto sobre Conservación de Alimentos por Irradiación (CIECAI). Informe téchnico y bases para una legislación. Documento CI–66/4/3.

FAO/IAEA 1966 International Symposium on Irradiation of Food, Karlsruhe, June.

FAO 1966 Catches and landings. *Yb. Fish. Statist.*, 20.

FRAZIER, W C 1962 *Microbiología de los alimentos*, Editorial Acribia, Zaragoza.

HANNAN, R S 1956 *Research on the Science and Technology of Food Preservation by Ionizing Radiation*, Chemical Publishing Co. Inc., New York.

HIDALGO NAVARROL, F 1959 Tecnología e higiene de la conservación del pescado.

IAEA/FAO/OMS 1964 Rapport d'un comité mixte d'experts. Les bases techniques de la reglementation des aliments irradiés, Rome.

IAEA/FAO/OMS 1964–7 Information Center for Food Irradiation. *Quarterly International Newsletter*, Saclay, France.

LOPEZ-CAPONT, F 1963 *Las conservas de pescado españolas en el Mercado Común.*

PRUD'HOME, M 1957 *Inspection Sanitaire des Poissons, Mollusques et Crustacés*, Editorial Vigot Frères, Paris.

RHODES, D N 1963 *La Pasteurisation du Poisson par les Radiationes Ionisantes*, Agence Européene pour l'Energie Nucleaire.

RONDENAY, F 1966 *Programmes Etrangers de Recherches sur l'Irradiation des Denrées Alimentaires*, Société Conservatome.

SINDICATO NACIONAL DE PESCA *Boletín de Información*, mayo y junio. 1966

SINDICATO NACIONAL DE PESCA 1966 Conservas de productos de la pesca. Publicación propia.

SINHUBER, R O 1966 *The Development of Radiation Sterilised Seafood Products*, Department of Food Science and Technology, Oregon State University.

SOUDAN, FRANCE 1965 *La Conservation par le Froid des Poissons, Crustacés et Mollusques*, Ballière et Fils, Paris, p. 377.

SYDNEY, J 1964 *Massive Radiation Techniques*, George Newnes Limited, Londres.

VIDAL, P 1965 *La Radioexposition des Produits de la Mer*, Société Conservatome.

L'expérience italienne dans le secteur de la radiopasteurisation des produits de la pêche

par D. Massa et A. Perna

L'expérience italienne dans le secteur de la radiopasteurisation des produits de la pêche

Après avoir brièvement décrit les possibilités d'utilisation des techniques d'irradiation pour la conservation des produits de la pêche en Italie les auteurs présentent les résultats des examens bactériologiques et des essais organoleptiques effectués sur du merlu de la Méditerranée irradié à 0,3 Mrad. Le traitement aux radiations ionisantes est susceptible de prolonger la conservation des produits de la pêche réfrigérés d'un laps de temps jugé intéressant compte tenu des conditions du marché italien.

Italian experience in radiopasteurization of fishery products

The possibilities of using irradiation in Italy as a preservation method for seafood are briefly described; the authors then report on the results of bacteriological and taste panel tests on Mediterranean hake irradiated at a level of 0.3 Mrad. Irradiation can increase the shelf life of refrigerated seafoods to an extent that might affect favourably Italian market conditions.

La experiencia italiana en la radiopasterización de productos pesqueros

En este documento se presentan succintamente las posibilidades de la irradiación como método de conservación de productos pesqueros en Italia; luego se relatan los resultados bactereológicos y la evaluación hecha por paneles de catadores de la merluza del Mediterraneo irradiada a la dosis de 0.3 Mrad. La irradiación puede prolongar la vida comercial de los productos pesqueros refrigerados en un grado tal que podria afectar de modo muy favorable las condiciones del mercado italiano.

L'APPLICATION des radiations ionisantes dans le domaine de la pasteurisation du poisson prolonge sa durée de conservation par le froid et lui permet d'arriver à des points de vente et de consommation plus éloignés dans de meilleures conditions de fraîcheur et par conséquent de commercialisation.

On sait que cette technologie nouvelle se fonde rationnellement sur le fait que les doses pasteurisantes (0,1 à 0,5 Mrad) déterminent une réduction de l'ordre de 10^4 à 10^5 de la charge microbienne initiale, permettant de prolonger la durée de conservation par le froid (0 à 2°C, soit 32 à 35°F).

Plus le traitement par irradiation suit de près la capture et plus la durée de conservation du poisson réfrigéré pourra être prolongée.

En tout état de cause, il convient de signaler, compte tenu de notre expérience, que les modifications bio-chimiques affectant le produit ne permettent pas d'étendre sensiblement la limite de conservation par le froid du poisson radiopasteurisé; en effet, la charge microbienne n'est pas le seul facteur responsable de l'altération du poisson.

Ces modifications bio-chimiques sont particulièrement évidentes chez les poissons de petite taille, tels ceux qui constituent l'essentiel des ressources piscicoles de la Méditerranée et qui sont en général conservés et commercialisés entiers.

POSSIBILITES ITALIENNES

La production, l'importation et la consommation des produits de la pêche s'établissent comme suit, pour 1966: sur une consommation totale de 413.938 t, l'Italie a produit 256.316 t et importé 165.489 t; les exportations ont été négligeables: 7.867 t (Ministero della Marina Mercantile, 1966). La consommation des produits de la pêche est faible: environ 8 kg par an et par habitant. La consommation de poisson pourrait être largement accrue par une amélioration des conditions de production et de distribution susceptible de fournir aux consommateurs les plus éloignés un produit réfrigéré de meillure qualité.

Autre facteur d'augmentation de la consommation: le développement de la pêche atlantique, parallèlement à l'amélioration de la chaîne de distribution.

Les navires de pêche mécanisés étaient en 1966 au nombre de 3.752, dont 1.043 dotés d'installations frigorifiques; 234 d'entre eux sont munis de moteurs de 250 ch ou plus (Ministero della Marina Mercantile, 1966); certains sont équipés pour la pêche océanique.

Malgré l'étendue des côtes italiennes, le poisson réfrigéré doit fréquemment effectuer des trajets importants pour atteindre les grands centres de consommation du Nord et du Centre où la densité de la population et le taux de consommation d'aliments riches en protéines sont particulièrement élevés.

Etant donné la longueur du trajet à parcourir, le poisson arrive aux centres de grande consommation à la limite de la durée de conservation; la marge de temps disponible pour la vente est de ce fait singulièrement réduite.

S'il devenait possible de prolonger, ne fût-ce que de quelques jours, la durée de conservation du poisson réfrigéré, on assisterait à une augmentation de la demande pour un produit de qualité meilleure et plus constante qui entraînerait une exploitation accrue du potentiel de pêche de la Méditerranée.

EXPERIENCES ITALIENNES SUR LA RADIOPASTEURISATION DU POISSON

Nos recherches ont porté sur le merlu (*Merluccius merluccius*), qui constitue l'une des espèces les plus prisées de la Méditerranée. Des échantillons très frais ont été emballés sous plastique transparent (cellophane—

TABLEAU 1. MOYENNE DES CARACTÈRES ORGANOLEPTIQUES OBSERVÈS DANS LES ÉCHANTILLONS IRRADIÉS OU NON, A DIFFERENTS STADES DE L'ENTREPOSAGE

Caractères organoleptiques	*Durée de l'entreposage réfrigéré à +½°C (en jours)*													
	0		3		6		10		13		18		21	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Rigor mortis	oui	oui	non	non	non	non	non	non	non	non	non	non	non	non
Odeurs imputables à l'altération	non	non	non	non	?	non	oui	?	oui	?	oui	oui	oui	oui
Intégrité de la peau	oui	oui	oui	oui	oui	oui	oui	oui	oui	oui	oui	oui	oui	oui
Intégrité de l'abdomen	oui	oui	oui	oui	oui	oui	oui	oui	oui	oui	?	?	non	non
Brillant des couleurs	oui	oui	oui	oui	oui	oui	oui	oui	oui	oui	non	non	non	non
Comestibilité	oui	oui	oui	oui	?	oui	non	?	non	?	non	non	non	non
Présence de liquide dans le sachet	non	non	non	non	non	non	oui	oui	oui	oui	oui	oui	oui	oui

A, lot témoin non irradié; B, lot irradié.

polyéthylène) clos hermétiquement sous vide. Certains échantillons ont été conservés comme témoins; un second lot a été soumis aux radiations à la dose de 0,3 Mrad de l'appareil *Hotspot*, Mk IV, d'une capacité de 2,000 ci de ^{60}Co, du Centre de radiologie vétérinaire de l'Institut de Zooprophylaxie de Pérouse.

Les deux lots ont été mis sous réfrigération à la température de 2°C immédiatement après le traitement.

Un premier contrôle a été effectué sur quelques échantillons immédiatement avant le traitement; par la suite des échantillons de chacun des deux lots ont été observés tous les trois à cinq jours. L'examen portait sur les points suivants:

(1) examen superficiel de l'emballage et de son contenu;

(2) ouverture du paquet dans des conditions d'asepsie et prélèvements aux fins d'examen bactériologique;

(3) etude des caractères organoleptiques.

L'examen bactériologique par numération de la flore bactérienne aérobie totale, a été effectué suivant la méthode classique des prélèvements sur la partie postérieure du sujet comprise entre l'ouverture anale et la nageoire caudale, sans ablation de la peau et de l'arête centrale.

Après homogénéisation dans de l'eau de mer stérile, suivie de dilutions graduelles, un frottis a été préparé sur plaques de Petri contenant un terrain de ZoBel 2216. Au bout de six jours d'incubation à 20°C (68°F), on a procédé à la numération des colonies formées.

Les valeurs moyennes des caractères organoleptiques observés et des numérations bactériennes figurent aux tableaux 1 et 2 respectivement (Massa, Perna and Begliomini, 1964).

Dans le cadre de nos recherches sur la conservation des poissons de la Méditerranée par l'effet des radiations ionisantes, nous avons effectué une série d'essais gustatifs sur les produits irradiés afin de déterminer si le traitement qui, aux doses employées (0,3 Mrad), prolonge la durée de conservation de trois à sept jours conserve également les qualités organoleptiques et gustatives caractéristiques du produit frais. En outre, l'apparition éventuelle d'odeurs ou de saveurs imputables au traitement par irradiation pouvait ainsi être mise en évidence.

Les essais ont porté sur les trois catégories de produits suivantes:

(1) merlu réfrigéré sans pré-emballage en sachets de matière plastique (système traditionnel);

(2) échantillons-témoins réfrigérés, pré-emballés sous vide en sachets de cellophane-polyéthylène;

(3) merlu pré-emballé sous vide en sachets de cellophane-polyéthylène, pasteurisé par irradiation à 0,3 Mrad puis réfrigéré.

Des échantillons cuits à la vapeur ont été soumis de deux en deux jours à l'appréciation d'un groupe de huit dégustateurs spécialistes, appliquant une technique spéciale décrite par ailleurs (Massa, Perna and Begliomini, 1965).

TABLEAU 2. NOMBRE MOYEN DE GERMES PAR GRAMME DE CHAIR DANS LES ECHANTILLONS IRRADIES OU NON, A DIFFERENTS STADES DE L'ENTREPOSAGE

Durée de l'entreposage	*Lot témoin*	*Lot irradié*
0	435.000	—
3	4.400.000	n.c.
6	155.000.000	5.600
10	900.000.000	144.500
13	2.000.000.000	625.000
18	3.750.000.000	42.000.000
21	—	570.000.000

CONCLUSIONS

Sur la base des examens microbiologiques et organoleptiques, nous pouvons affirmer que:

(a) les échantillons-témoins ont en général atteint le seuil de comestibilité (signe "?" dans le tableau 1) dès le sixième jour d'entreposage, avec une charge bactérienne de 155.000.000 germes/g;

(b) les échantillons irradiés ont atteint le seuil de comestibilité du fait de l'odeur de fermentation qu'ils présentaient après 10 à 13 jours d'entreposage, alors que la charge bactérienne moyenne était demeurée relativement faible (144.500 et 625.000 germes/g);

(c) pour ce qui est des examens organoleptiques, les échantillons pré-emballés, irradiés ou non, ont obtenu dans tous les cas des notes supérieures à celles des échantillons non pré-emballés. Ces derniers étaient devenus incomestibles après six jours d'entreposage alors que les échantillons irradiés pouvaient être consommés 13 jours après le traitement, contrairement aux échantillons-témoins sous emballage de plastique, jugés incomestibles après 11 jours.

D'autres essais organoleptiques, ainsi que des dosages chimiques (TMA et dialdéhyde malonique) et la culture d'anaérobies sont en cours.

On peut conclure pour l'instant en affirmant que l'irradiation associée à des précautions particulières (utilisation de récipients hermétiques, traitement thermique, etc.) est susceptible d'accroître sensiblement la durée de conservation des produits de la pêche.

Bibliographie

MASSA, D, PERNA, A et BEGLIOMINI, A Richerche batterio-
1964 logiche su naselli pasteurizzati con radiazioni ionizzanti. *Atti Soc. ital. Sci. vet.*, XVIII, 559.

MASSA, D, PERNA, A et BEGLIOMINI, A Ulteriori ricerche su
1965 naselli pasteurizzati con radiazioni ionizzanti. *Atti Soc. ital. Sci. vet.*, XIX, 573.

MINISTERO DELLA MARINA MERCANTILE *La pesca marittima in*
1966 *Italia.*

DISCUSSION

Bersamin (Philippines): Certain agencies of the Philippine Government are considering putting up a pilot food irradiation plant in Manila for experimental studies on fruits, fish, vegetables and meats and there are many questions which require answers. How successful would a multi-purpose plant like this be? What are some guiding points for economy and maximum efficiency? Some of our problems are: (a) Government research is always plagued by lack of finances; (b) our local reactor is a very inadequate source of the necessary isotopes. There is no such kind of pilot plant in the country at present but the agencies doing research on foods have generated enough interest to undertake irradiation studies in their respective areas. Should the Government initiate a project of this nature? The question of private interests taking this matter up depends very much on the success of Government agencies. There is a growing feeling in some quarters that at this stage of Philippine economy, projects of this nature would not be profitable.

However, some preliminary studies done on fruits such as mangoes and bananas indicate that the ripening process can be retarded, colour can be improved and natural flavour maintained. There are now plans to extend these studies to rice and corn where the main problem is with weevils which very much shorten the storage life of these cereals. No work has been done on fish as yet.

What operating procedures are recommended to insure the maximum success of a multi-purpose plant managed by several agencies working on various types of foods?

Guillot (France): Je signale l'inquiétude que donne actuellement aux vétérinaires hygiénistes de l'Alimentation, en France, la présence de *Clostridium botulinum* type E dans certains poissons, tels les saumons, en tranches, en emballage sous vide.

Les communications présentées ne traitent que de l'influence des rayonnements sur les microorganismes *aérobies* et non anaérobies. Plusieurs travaux publiés dans le monde concernent ces derniers. Je pense qu'il serait intéressant pour les membres présents d'avoir l'avis des spécialistes sur la radiosensibilité des spores de *Clostridium botulinum* type E.

Vidal (France): L'irradiation est un nouveau procédé de conservation qui doit apporter une importante amélioration dans la production et la commercialisation des produits de la pêche. Etant donné les résultats de l'irradiation et les propriétés des radiations ionisantes il est humain de demander à ce nouveau procédé le maximum et, notamment d'apporter des solutions aux problèmes non résolus par les autres procédés.

Dans le cas du *Clostridium botulinum*, il faut reconnaître que jusqu'à une date récente ce problème était peu étudié. Les spécialistes bactériologistes de l'irradiation se sont penchés sur le problème et ont de ce fait accumulé un ensemble important de connaissances.

Pour les produits frais et surgelés une brochure de l'OECD intitulée "Règlements sanitaires pour le poisson et les produits de la pêche" indique par la voix d'un de ses experts (brochure 51): ". . . Il est plus difficile de savoir s'il est nécessaire et utile d'effectuer un contrôle bactériologique et quelle méthode il faudrail employer à cet effet. . . . Il est évident que la présence de bactéries pathogènes et de bactéries provoquant l'intoxication présente un danger alimentaire certain. Il conviendrait de mentionner d'abord, qu'en règle générale, la présence d'un petit nombre d'organismes toxiques dans les produits alimentaires ne présente aucun danger. Le présence de *Cl. botulinum* dans les aliments congelés ne semble pas non plus être nuisible. Celui-ci ne devient dangereux que quand le germe se développe dans le substrat et sécrète une quantité suffisante des toxines; pour se développer il doit être dans un milieu complètement anaérobie et à une température très supérieure à 0°C."

Le problème peut se poser du fait de l'augmentation de la durée de conservation si une température basse ne peut êre maintenue. Les spécialistes ont montré qu'à basse température le danger de production de toxines est peu à craindre. Le concentration importante de *Cl. botulinum* peut être un facteur important. Malgré le peu d'informations existant à l'heure actuelle, on peut dire que pratiquement la concentration de *Cl. botulinum* n'est pas supérieure à 10^{-1}/g. Il convient dans las travaux de recherche de tenir compte de ce fait et de ne pas les effectuer avec des contaminations de l'ordre de 10^4/g. D'ailleurs un produit contaminé d'une telle façon serait à éliminer.

Certes, un emballage présentant un milieu anaérobie est en principe susceptible d'augmenter le risque, toutefois, le matériau plastique et la pratique commerciale d'emballage ne présentent pas un milieu anaérobie parfait.

Quoi qu'il en soit, il est naturel de demander le maximum à l'irradiation et d'essayer d'obtenir ce maximum mais pratiquement il convient de ne pas formuler des exigences qui d'ailleurs condamneraient d'autres procédés de conservation.

Pace (U.S.A.): The following are important points in regard to *Clostridium botulinum* in radiation-pasteurized foods:

(1) Low incidence—data on contamination levels is not extensive and data on the minimum contamination levels required for toxin production under given conditions is quite scant.

(2) Holding temperatures—the temperatures at which the food is held in the home must also be considered in assessing the overall problem.

(3) Type of pack—a strict anaerobic pack is not essential for outgrowth and toxin production by *Cl. botulinum*; anaerobic conditions existing between adjacent fillets are known to be sufficient.

(4) Inoculation levels used in research studies (10^2, 10^4 and 10^6 spores/g of fish) are certainly far in excess of naturally occurring levels; if spoilage occurs before toxin production at these levels, however, there can be little question that the material as produced commercially, and contaminated only at naturally-occurring levels, should be safe in so far as *Cl. botulinum* toxin is concerned.

(5) Types of *Cl. botulinum* other than type E—these other types cannot be ignored as surveys have revealed that types A and C are prevalent in Latin American estuaries.

Charm (U.S.A.): Should not irradiated pasteurized fish have the same degree of safety with respect to botulism as does canned food? It is somewhat inconceivable that a lower degree of safety with respect to botulism could exist in irradiated pasteurized fish than is allowed in canned food. If this is the case, the irradiation dose that might be applied to fish which is packaged will be greatly restricted, and may greatly influence the economics of this process.

Kovacs (Federal Republic of Germany): In connection with the question of safety or rather stability of irradiation-sterilized foods, I would like to repeat Ingram's suggestion at the Karlsruhe Symposium on Irradiation of Food i.e. that to irradiated (radurized or radicized) foods the same demands of "commercial sterility" should be applied, as to heat sterilized or pasteurized foods.

Heen (Norway): In the past there has been concern on the part of some health authorities that the mutagenic effects of irradiation may give rise to new strains of bacteria which are more pathogenic or else may cause harmless bacteria to become pathogenic. Is there any evidence to support these fears? We now know of many compounds which are potentially mutagenic. Mild heat treatment which has been used for centuries in the preservation of food and possibly even freezing may cause mutations. It appears that there will always be some risk of harmful bacteria being created through mutations induced by active radicals metabolically split from naturally occurring organic substances. Why should there be particular concern over irradiation-induced mutations.

Liston (U.S.A.): The question of mutagenic effects, of course, is under some study in the U.S. program. My impression from our own work and that of other people is that this is not a serious problem at the dose levels which are proposed for radiation-pasteurization. There is, of course, as Heen indicated, the possibility of secondary effects due to the development of mutagenic compounds. Again we have no positive evidence on this. However, it is a somewhat remote possibility, I think. Perhaps some of the other U.S. representatives who have knowledge of this might care to comment on Heen's point.

Goresline (IAEA): We have had two panels held by the IAEA in which this has been discussed. As far as I am aware on a long-term basis of irradiation, no one has come up with a mutation where there has been any increase in pathogenicity or a non-pathogenic organism becoming pathogenic. Work has shown that if you repeatedly irradiate, let grow, irradiate, let grow, by the time you reach 20 passes and regrowths you can determine that there is increased resistance to irradiation. These people, using Salmonella, did not demonstrate any increased pathogenicity or toxicity, and it was determined that, up to the number of five or six passes, there was no change at all. So there is a possibility that you might increase resistance to some extent through a process in which you did irradiate over and over again. But I know of no cases in which there has been any increase in pathogenicity.

Liston (U.S.A.): You refer to the Canadian work I think. The most recent information I have on that is that the resistance is not as stable as they had believed. The organisms tend to revert to a less-resistant form.

Pace (U.S.A.): Two studies regarding changes in radio-resistance and virulence of micro-organisms are presently being conducted under the U.S. Atomic Energy Commission contracts. One dealing with Salmonella has progressed through 14 recyclings with no increase in virulence. There has been an increase in radio-resistance but this increase appears to be transient, disappearing after a number of generations without further radiation exposure. The second study is concerned with viruses. So far, this study has been concerned with precise characterization of the entero-viruses being studied and the portion of the study dealing with changes in cirulence and/or radio-resistance, if any, is only in its initial stages.

Diehl (Federal Republic of Germany): I would like to add a comment concerning the question of increasing radio-resistance of micro-organisms by repeated irradiations. This is a most important question. It is asked by the public health authorities whenever we talk about the possibility of getting clearances for irradiated foods. To our knowledge, nobody had studied this problem with fungi. We have, therefore, investigated the radiation resistance of various species and strains of fungi after as many as 10 repeated radiation treatments. We found that there is a certain variation in the resistance of different strains of one species. From the less radiation-resistant strains we could obtain "mutants" with increased resistance. However, this increase never reached a higher level than that which was found in the more resistant strains at the beginning of the experiments.

Now a more general remark. I regret very much that in this session on the quality of irradiated fish, we did not have a report by a toxicologist on animal feeding studies with irradiated fish. I believe that the greatest obstacle to the practical application of fish irradiation is not any technological difficulty, but rather the lack of clearances. Some of the responsible persons in the health ministries are still under the impression that not enough animal feeding studies have been done. When the published proceedings of this Conference will become available, the sceptics will have another opportunity to point out that at conferences of this type only the technologists get together and tell each other what a wonderful new process they have, but that the question of wholesomeness was not sufficiently discussed. Even if we are all convinced that irradiated food is as wholesome as non-irradiated, we should have at least one outstanding toxicologist at each conference of this sort to talk about the animal feeding studies that have been carried out, and to point out how much work has actually been done in this area.

Massa (Italy): The experiments so far carried out in Italy on 0.5 Mrad irradiated foot and mouth disease (FMD) virus, after more than 2,000 recyclings, show that no induced radio-resistance or increase in infectivity takes place.

del Real (Spain): Queremos hacer unas consideraciones generales sobre algunas de las manipulaciones que aquí se han hecho especialmente en lo que concierne a la posibilidad práctica de la utilización de las radiaciones como método de conservación de pescado sobre todo desde un punto de vista de reglamentaciones oficiales.

En general, para que un procedimiento se considere aprobado para la conservación de alimentos, deben considerarse previamente los siguientes puntos:

1° *Inocuidad del método.* Con respecto a este punto queremos destacar aquí la intervención que ha tenido esta mañana el Profesor Diehl en la que lamentaba la falta de información científica sobre la inocuidad del pescado irradiado y la falta de experiencias en gran escala realizadas con animales de experimentación. Nosotros consideramos también que efectivamente hubiera sido del máximo interés disponer en esta reunión de la información adecuada sobre este punto.

2° *Eficacia.* Otro punto a considerar es el de la eficacia de la irradiación en la conservación del pescado. Numerosos documentos presentados sobre el tema demuestran la posibilidad de prolongar la conservación del pescado, aunque también se ha apreciado la dificultad que esto supone cuando se realiza con pescado recién capturado. Consecuentemente a la

eficacia, sería del mayor interés conocer la dosis más adecuada para conseguir la prolongación del estado sanitario del pescado.

3° *Necesidad.* El siguiente punto a considerar es el de la necesidad de emplear el método de conservación en estudio, teniendo en cuenta que su utilización está en cierto modo restringida a un determinado sector de la comercialización del pescado (pescado fresco principalmente). Por ello, su necesidad está condicionada por la eficacia y éste es un punto a valorar en las condiciones de comercialización de cada área geográfica en particular.

4° *Educación sanitaria.* Teniendo en cuenta las disposiciones nacionales e internacionales del etiquetado de alimentos consideramos del mayor interés que a los aspectos relacionados con la educación sanitaria del consumidor se les dedique especial atención, mediante programas que orienten la opinión del consumidor hacia la inocuidad y eficacia de los métodos de radiación del pescado en combinación con el empleo del frío.

Pace (U.S.A.): Animal feeding studies, conducted in the United States to date on irradiated foods have produced no harmful results which have been attributal to irradiation. These studies have involved the feeding of irradiated foods, generally at a level of 35 per cent of the total dietary solids, to thousands of rats and mice, hundreds of dogs and chickens, and a number of pigs and monkeys. The duration of these studies has been from several months to two years. As with all investigations into unknown areas, the protocol for conduct of these studies has undergone considerable change from the start to the present time. This has been due to the posing of new questions from time to time. Our protocol now seems to be relatively stable and generally involves the following:

(1) Use of three species of test animals—rat, dog and chicken.

(2) Feeding the test material at a level of 35 per cent of the dietary solids or at the maximum level tolerated by the species.

(3) Use of four groups within each species; one group fed on normal diet for the species, one group fed the test food unirradiated, one group fed the test food irradiated at the level proposed to use and one group fed the test food irradiated at a level two times that proposed.

(4) Blood studies at no-month and three-month intervals —this includes red blood cell counts, white blood cell counts (both total and differential), haemoglobin and haematocrit levels and studies on certain blood enzymes (serum glutamic oxalacetic transaminase, serum glutamic pyruvic transaminase, and monamine oxidase).

(5) Gross pathology—on selected animals sacrificed at three-month intervals on all animals at the completion of the study.

(6) Microscopic pathology—on all grossly abnormal tissues and on tissues of all animals sacrificed for gross pathology.

(7) Reproductive studies—dogs through two generations, rats and chickens through four generations.

(8) Daily observations food intake, weight gain longevity.

(9) Statistical analysis of all data.

Animals used at the start of a study: 320 rats, 320 chickens, 80 dogs. Among the studies conducted early in the program was one on radation-sterilized cod. Ninety-day studies have been conducted on cod, haddock and four other species of fish. A two-year study on radiation-pasteurized soft-shell clams will soon be concluded.

van Hoeck (Belgium): Le problème de la comestibilité et de l'innocuité des aliments irradiés dépasse le seul aspect microbiologique. Un récent rapport préparé par un Comité consultatif scientifique pour le Président des Etats-Unis sur "The World Food Problem" (le problème alimentaire mondial) ne consacre que quelques lignes à l'irradiation (sur 800 pages environ) et dit que: "de récentes études suggèrent que des effets nuisibles peuvent être transmis aux aliments par des intermédiaires stables et toxiques. La signification de ces études ne pourra être établie sans exécution de larges études de nutrition. Ces problèmes et d'autres indiquent que l'irradiation n'aura probablement pas d'application significative pour la conservation des aliments dans un avenir prévisible".

Trop peu a été consacré au cours de cette réunion aux problèmes de comestibilité. Il y a deux ans la FAO, l'OMS et l'AIEA ont émis des recommandations sur "les bases de la règlementation des aliments irradiés" qui décrivaient les procédés expérimentaux à appliquer pour l'étude de la comestibilité. Je suggère que les mêmes organismes organisent une discussion approfondie sur les résultats des travaux comme ceux que vient de décrire succinctement le Dr. Pace.

Economic Feasibility of Radiopasteurization of Fish

by L. W. van Meir

Economic feasibility of radiopasteurization of fish

Radiopasteurization of fish is reviewed for its potential to reduce the overall costs of processing and distribution, and to enable industry to increase the demand for fish. Industry must be able to anticipate sufficient financial gains from either or both of these factors before they will be willing to bear the risk of investing in the capital necessary to adopt radiopasteurization.

On the basis of preliminary data, it appears that radiopasteurization offers some potential for decreasing costs and a great potential for increasing demand for the fresh product form of several species of fish. Thus, the technology meets the necessary conditions for its commercial adoption.

The question of implementing the adoption of radiopasteurization gives rise to many problems of an institutional nature that will have to be considered not only by industry but by governments as well. These problems will require additional study and policy determination as well as technical research to provide adequate knowledge for policy formation and program development.

La praticabilité economique de la radiopasteurisation du poisson

La radiopasteurisation du poisson fait l'objet d'un examen en vue de déterminer dans quelle mesure il est possible de réduire les frais de traitement et de distribution et d'accroître la demande industrielle de poisson.

L'industrie ne sera disposée à encourir le risque inhérent aux investissements de capitaux nécessaires pour adopter la radiopasteurisation que si elle peut espérer tirer de l'un au moins de ces deux facteurs un bénéfice suffisant.

L'étude des données préliminaires montre que la radio-pasteurisation devrait permettre de réduire quelque peu les frais et d'accroître considérablement la demande de plusieurs espèces de poisson, sous forme de produit frais. La technologie trouve ainsi les conditions nécessaires à son adoption industrielle.

La mise en oeuvre de la radiopasteurisation suscite de nombreux problèmes de nature institutionnelle, qui devront être examinés tant par l'industrie que par les gouvernements. Pour résoudre ces problèmes, il conviendra d'en poursuivre l'examen, d'élaborer des décisions de principe et d'effectuer les recherches techniques destinées à permettre la formulation des principes généraux et la mise au point des programmes.

Viabilidad económica de la radiopasterización del pescado

Se examinan las posibilidades de la radiopasterización de reducir los costos generales de la elaboración y distribución y de permitir que la industria satisfaga una demanda creciente de pescado. Antes de correr el riesgo de invertir el capital necesario para adoptar la radiopasterización, la industria tiene que estar segura de que uno o ambos de estos factores la van a dejar suficientes beneficios económicos.

Se desprende de los datos preliminares que la radiopasterización ofrece algunas posibilidades de reducir los costos y muchas de incrementar la demanda de varias especies de pescado fresco, con lo cual la tecnología encuentra las soluciones necesarias para su adopción comercial.

La adopción de la radiopasterización plantea varios problemas de carácter institucional que tendrán que examinarse no sólo por la industria, sino también por los gobiernos. Estos problemas exigirán estudios ulteriores y determinaciones políticas, así como investigaciones técnicas para obtener conocimientos suficientes para formular políticas y programas.

IS radiopasteurization of fish an economically feasible technology? Unfortunately the complete array of data necessary to provide a definitive answer to this question are not available at the present time. However, it is a relevant question, and we do have some facts, that can be brought to bear on the topic.

Most important is that we take a good *a priori* look at what is necessary for radiopasteurization to be adopted commercially, and assure that the facts necessary to answer the question are generated as a part of our developmental studies. We can, at the same time, pose some of the additional problems or considerations that will arise if, and when, radiopasteurization comes into commercial use.

This paper is based on a pasteurization level dosage of *irradiation. Thus, we are considering a product that still* requires a cold chain or iced distribution just as in the case of distribution of fresh fishery products. Therefore, at the outset we can eliminate from further consideration radiopasteurization as a means of enhancing the protein supply of many areas where these facilities do not exist. Furthermore, the economic feasibility of radiopasteurization of fish will vary considerably from country to country depending on institutional arrangements and consuming habits. Although the specific data cited here are based on experiences in the United States, the general principles will apply to most countries.

Radiopasteurization may eventually find many uses in the field of fish processing and distribution. However, in order for fish processors to turn from conventional processing methods to irradiation, or to add an irradiation phase to the processing line, it must be to their financial advantage to do so. This financial advantage can result from either of two sources. First, irradiation may reduce costs of processing and distribution. If this occurs, then the marketing margins of the firm will be improved without costing the consumer more, or causing a reduction in the price of fish to the fisherman. Second, irradiation may result in a significant increase in demand for a particular product. In this case, a higher price could be realized for the volume being sold, or the firm would be able to expand its volume without having to drop the price. Thus, even if irradiation increased the cost of processing and distribution, a net financial advantage could be gained if the increase in demand is sufficient to more than offset the additional processing costs.

IRRADIATION IN THE DISTRIBUTION OF FRESH FISH

The case for cost reduction

In the case of fresh fish distribution, irradiation will add an additional step to the process and, therefore, will add costs in the form of additional handling and for the

capital and labour utilized in the irradiation process itself. On the other hand, costs in the form of actual spoilage, or lower prices received for the sale of fish about to go out of condition, may be eliminated as a result of irradiation. Therefore, the net cost result for utilization of irradiation in fresh fish distribution hinges on the relationship between the cost of irradiation and the visible cost savings from decreased spoilage.

It has been estimated that the cost of irradiation would be 4.2 c/kg (1.9 c/lb) if an annual throughput of 5,715 t (6,300 s. t) was achieved in the small scale Marine Products Irradiator at the Bureau of Commercial Fisheries Technological Laboratory at Gloucester, Massachusetts (Joint Committee on Atomic Energy, 1965).

In a study made for the Atomic Energy Commission of the United States, an engineering firm estimated irradiation costs to be between 2.6 c/kg (1.19 c/lb) and 3.4 c/kg (1.56 c/lb) depending on the length of the amortization period and the cost of ^{60}Co (David Yankelevich Inc., 1967).

These costs were for a 9,525 t/year (10,500 s. t/year) throughput based on a 16 h/day utilization. If the irradiator could be used a full 24 h/day, costs would be even lower. Therefore, preliminary indications are that the costs of irradiation likely would fall in the range of 2.2 to 3.3 c/kg (1.0 to 1.5 c/lb) for irradiating fish.

Several aspects of irradiation suggest that if sufficient volume of throughput can be achieved the cost can be reduced substantially. Fixed costs would comprise more than 50 per cent of total costs. Therefore, "spreading the overhead" over a larger throughput will enable the average cost per unit processed to be decreased over a wide range of utilization of the facility. Furthermore, the large proportion of total cost represented by fixed costs implies that economies of scale may be realized by building a larger volume installation if sufficient raw material is available to keep it fully utilized. Also, recent experiments at lower dosage (100,000 rad) have produced excellent results. Thus, if sufficient extension of shelf life can be achieved at lower dosage, the throughput can be increased accordingly.

The cost savings that would accrue from irradiation due to reduced spoilage and lower prices for distressed sales will be a function of the rate of occurrence and the value of the product involved. The cost incidence for spoilage likely falls initially on the retailer. Generally, wholesalers are able to move fish to the next buyer before spoilage occurs. However, at times they may have to drop price to move a quantity of fish that may be nearing the end of its shelf life.

Complete data are not available on the rate of spoilage by species, product form, geographical area, type of market outlet, or season. In the aforementioned study for the Atomic Energy Commission, spoilage of fresh fish was estimated to be 5 per cent of market volume by weight. Assuming this to be an accurate estimate of this parameter in the fresh fish distribution system, the break even wholesale price for irradiation to start yielding a financial advantage would be 44 to 66 c/kg (20 to 30 c/lb). If the retailer considered that he had some costs over and above the wholesale price of fish tied up in spoiled fish, then the break even wholesale price of fish would be less than 44 to 66 c/kg (20 to 30 c/lb) according to the extent of such costs. Consequently, all fresh fish which average over 44 to 66 c/kg (20 to 30 c/lb) at wholesale potentially could represent a direct financial advantage to the trade as a result of elimination of spoilage through irradiation. Based on 1965 average wholesale prices, cod (*Gadus morhua*), haddock (*Gadus aeglefinus*), ocean perch (*Sebastes* spp.), flounder, pollock (*Pollachius pollachius*), halibut (*Hippoglossus* spp.), salmon (*Oncorhynchus* spp.), red snapper (*Lutjanus black fordi*), yellow perch (*Perca flavescens*), yellow pike (*Stizostedion vitreum vitreum*), catfish (*Pilodictis olivaris*), lake whitefish (*Coregonus* spp.), and scallops (*Pactenidae* spp.) all command a sufficiently high price at wholesale to be potential candidates for sufficient cost savings to more than cover the costs of irradiation.

The case of increasing demand

The effective demand function for a product is the aggregate of the demand functions of all individual buyers in the market. At relatively high prices for a product, only those buyers who have a high preference for the product will be included in the effective market demand. At lower prices, not only will buyers who were in the market at the higher price tend to buy more, but buyers with a lower preference for the product will be enticed into the market. Furthermore, demand will depend on the potential number of consuming units within the market area in which the product is being distributed. An action that widens the distribution area, tends to bring a larger number of buying units within the market and therefore tends to increase the demand for the commodity.

The effectiveness of radiopasteurization is generally expressed in terms of number of days increase or extension of the shelf life of fish. The effectiveness could also be described in terms of marketing radius, i.e. lengthened shelf life permits distribution to more distant consumng centres. Thus, for example, irradiation may extend the shelf life 10 days which could, in turn, increase the marketing radius from 800 to 1,600 or 2,400 km (500 to 1,000 or 1,500 miles).

Let D_1 represent the demand for a species of fish where the present technology limits the marketing area to a radius of 800 km (500 miles). If, then, a new technology, i.e. irradiation, permits extension of the marketing area to a radius of 1,600 km (1,000 miles), the added number of buyers brought into the market may result in an increase in demand to D_2. If Q_0 quantity of a species of fish were being distributed at price P_0, this same quantity of fish would now bring a price of P_1. This, in essence, results from shifting consumption from buyers with lowest preference for fish in the former zone of distribution to buyers with a higher preference in the market area added.

In order for the increase in demand to produce sufficient incentive for industry to adopt irradiation, the price increase from P_0 to P_1 must more than offset the increased processing and distribution cost associated with irradiation. Again, if irradiation costs are assumed to fall in the range of 2.2 to 3.3 c/kg (1.0 to 1.5 c/lb) the increase in price need only be in the neighbourhood of 1.5 to

TABLE 1. LANDINGS, FREEZINGS AND EX-VESSEL PRICE OF HADDOCK FOR 1966

Month	Landings* (1,000 lb)	Freezings* (1,000 lb)	Ex-vessel price* (U.S. cent)
January	7,142	685	15.4
February	8,982	2,178	12.5
March	12,875	4,300	11.1
April	11,457	2,880	11.4
May	10,912	2,983	9.6
June	13,104	4,088	9.9
July	8,662	2,045	12.3
August	11,145	3,205	11.8
September	10,703	2,803	12.4
October	6,926	680	15.0
November	6,350	1,293	13.6
December	6,330	1,428	13.1
Total	114,588	28,568	Average 12.0

* Drawn weight basis.

3 per cent for fish with a retail price of 110 to 154 c/kg (50 to 70 c/lb). It would be reasonable to expect much greater increase in price for many species of fish from the market extension that would be feasible through irradiation.

An increase in demand may also be exploited through expanding volume. In fig 1 the volume sold could be increased from Q_0 to Q_1 at the price P_0. This aspect of an increase in demand offers an advantage if either a fishery resource is capable of absorbing increased fishing effort, or if a significant amount of a species of fish is being sold as frozen fish. For example, where frozen haddock fillets

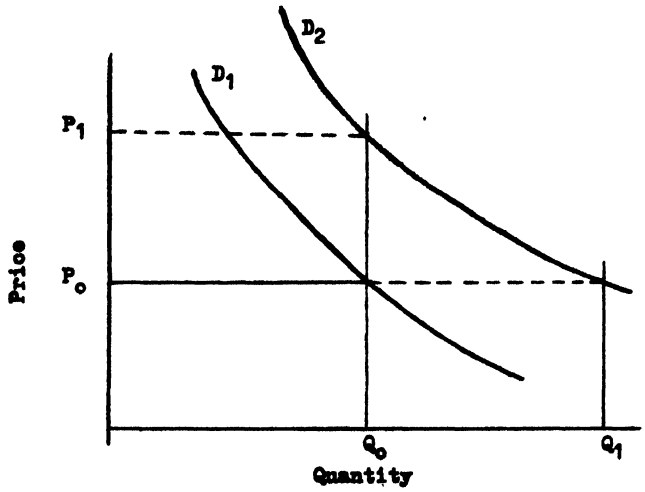


Fig 1. Illustration of an increase in demand

retail for 130 c/kg (59 c/lb), fresh haddock fillets in the same store may sell for 174 c/kg (79 c/lb). Even if processing and distribution costs for irradiated fish were 15 to 22 c/kg (7 to 10 c/lb) higher than for frozen fish fillets, the 44 c/kg (20 c/lb) price differential for fresh fish would provide a substantial net profit for irradiation.

It must be emphasized that the function of smoothing out the seasonal variation in landings through freezing and storing cannot be replaced by radiopasteurization technology. The few days' extended shelf life from pasteurization dosage are not sufficient to permit a part of the spring seasonal peak landings to be stored for market the following fall and winter. What can be achieved though is a general change from frozen to fresh product form for part of the present frozen volume, thus improving the average ex-vessel value of the species. The total increase in value realized from the resource will depend on the ability of the industry to decrease the seasonal and daily variation in landings to permit a greater proportion of the annual catch to be sold in the fresh market.

As can be seen from table 1 (above), a 33 per cent increase in demand for fresh haddock would be necessary to enable all haddock now being frozen to be moved as fresh fish. It likely would not be feasible to expect that demand could be increased sufficiently to absorb all of the seasonal peak catch of the March–September period in the fresh fish market. However, a 10 per cent increase in demand would eliminate practically all freezings except in the March–September period, and would reduce significantly the volume of freezings during this period.

If demand were increased 10 per cent by irradiation, the increase in price realized from the volume of fish now being marketed fresh could add an additional $2.0 to $2.5 million to the retail value of haddock. Inasmuch as the demand for fresh haddock is relatively elastic, an additional gross retail value of $1.4 million might result from the diversion of fish from the frozen market to the fresh fish market. Even though these figures are very rough estimates, their magnitude suggests that potential advantages to be gained from increasing demand through radiopasteurization is substantial.

General industry wide considerations

Once irradiation comes into commercial use, an industry may realize additional positive effects on demand that the individual firm was not able to foresee or estimate in its decision-making process. These are limitations that stem from the present technology and apply equally to all firms in the industry and as such tend to be a part of the parameters of the trade under the current technology. One such example may be the tendency for retail outlets to buy on a limited basis to hold spoilage costs to a minimum. Thus, the industry may be foregoing a significant volume of sales by not having product available for potential buyers when they want it. If spontaneous buying, prompted by on-sight display and promotion technique is important, this could be quite significant. In fact, it may mean that the industry, within the present technology, is unable to make use of some of the most effective selling techniques.

Along the same line, potential repeat sale customers may be lost permanently as a result of a single sale of out-of-condition fish in an effort to hold spoilage losses to a minimum. Unfortunately, when substandard merchandizing practices become "par for the course", no individual firm can account its losses generated by these "industry accepted" practices. At the same time, the mere adoption of irradiation technology will not assure the elimination of such problems. It matters not, whether a customer is lost permanently as a result of someone

selling a spoiled piece of iced fish or a spoiled piece of irradiated fish. Therefore, irradiation, to be successful, will still require sound merchandizing and quality consciousness.

Another industry advantage that might eventually develop out of irradiation is greater price and volume stability. At the present time, daily volume of landings and prices may fluctuate through wide ranges. The reason for the wide price fluctuation is that when landings increase, the industry has to move down the demand curve to move the increased volume and may even have to divert a portion to freezers where costs are increased and end value less. The market price will be no higher than the marginal use, thus the market for frozen fish sets the price for the days landings.

The risk and uncertainty of the processor stemming from this pattern of daily fluctuations is compounded by a labour agreement which includes a guaranteed 40 h week to the fish cutters called up for the week. Consequently, the present harvesting, processing and distribution chain includes considerable inefficiencies and resulting costs. This may be improved if the extended shelf life achieved by irradiation would provide sufficient incentive and financial gain to prompt a more stable and efficient arrangement.

The potential for improved stability of product flow can be extended through the retail market. The retailer no doubt encounters increased risk on fish not sold at the end of the week. Therefore, he tries not to be caught with fish that have to be carried over to the following week's market. However, again extended shelf life for irradiated fish may remove this risk. As a result, a more efficient pattern of delivery to the retail outlet may be possible.

IRRADIATION IN THE DISTRIBUTION OF FROZEN FISH

The experimental work to date on irradiation of fish has been confined largely to fresh fish. However, further work in the future may develop equally as well the technique of irradiating frozen fish. If costs can be kept within the range mentioned above, then irradiation of frozen fish may offer advantages also.

One of the most obvious advantages that may develop in irradiating frozen fish is as a means of meeting Food and Drug Administration inspection standards for bacterial count. This aspect likely will become increasingly important in the future if Food and Drug Administration increases its inspection for bacterial count.

A second application in the distribution of frozen fish would be to facilitate thawing out frozen fish at retail service counters. If a low bacterial count in frozen fish can be achieved through irradiation, then the shelf life after thawing would be extended and spoilage costs after thawing reduced. International trade in fishery products may be able to realize considerable advantages in the irradiation of frozen fish and shellfish that are to be used as raw material for further processing in the importing countries. Therefore, frozen shrimp which is imported to be used in producing breaded or individual quick frozen (IQF) shrimp products, may be irradiated as a means of keeping bacterial count down both from the standpoint of passing inspection and slowing the rate of quality degradation during the processing period. In fact, irradiation may be a cost-reducing technique compared with present efforts to accomplish these objectives.

PROBLEMS TO BE CONSIDERED IN THE APPLICATION OF IRRADIATION

The existence of potential financial advantages from irradiation is necessary to its being applied commercially. However, this in itself will not assure either application or achieving the utmost potential from the new technology.

Institutional problems in connection with irradiation

The present structure and set of institutional arrangements in fish harvesting, processing, distribution and consumption have all developed over time in relation to present technology. It is questionable whether irradiation can be fit smoothly into the present institutional pattern or even if it can be introduced at all without some substantial changes in industry structure.

It will be necessary to develop more specific policy towards irradiation as we move closer to introducing irradiation into commercial use. One policy area that is under consideration at the present time is Food and Drug Administration approval. Closely connected with this will be requirements about labelling and identification as well as perhaps standards of identity. An extensive programme of consumer education may be necessary depending on the manner in which the above-mentioned questions are resolved.

We may face considerable concentration in processing and distribution of fish as a result of irradiation. If economies of scale are significant, a very large processing unit may give much lower operating costs. However, if a single firm develops the facility, it will be pulling raw material from other firms in the industry in order to maintain throughput at optimum capacity. For example, there are now more than 40 firms processing and distributing fish landed at Boston. Obviously, we could not expect to see 40 individual irradiators in use. Perhaps the facility will have to be considered as a public utility. Similarly, the question of on-board or on-shore irradiation poses the possibility of a radical change in the industry. Consequently, many issues must still be resolved before commercial irradiation becomes a reality.

Additional research needed

The research to date has been largely directed at the question of technological feasibility of radiopasteurization. However, once this question is answered in the affirmative, a complete new area of research becomes necessary. Such problems as optimum scale, location, engineering efficiency, flexibility, etc., all require additional research. Distribution, marketing and industry organization will also require additional research. Research will be needed to delineate the economic aspects of the commercial process itself. For example, how does the cost of irradiation increase with increments of shelf life extension? How much additional shelf life is needed per species to achieve the advantages of irradiation? These are only a few of the many questions that will

arise in connection with the commercial introduction of irradiation.

The broader industry problems will have to be studied by governments and will require appropriate government policies. At the same time, much of the research necessary to solve applied problems of the individual firms will be beyond the economic and technical capability of the firm. Therefore, if commercial adoption is to be implemented, this research likely will also have to be sponsored by governments.

References

JOINT COMMITTEE ON ATOMIC ENERGY 1965 *Hearings before the Subcommittee on Research, Development, and Radiation of the Joint Committee on Atomic Energy, 89th Congress of the United States*, U.S. Govt. Printing Office, Washington, D.C., p. 82.

DAVID YANKELEVICH INC. 1967 *Cost-benefit Study of Selected Products in Atomic Energy Commission's Low-dose Food Irradiation Program.* (MS.)

Irradiation of Fish at Sea

by J. H. Carver, T. J. Connors and J. W. Slavin

Irradiation of fish at sea

An engineering study has shown that it is possible to irradiate fish at sea, and several commercial shipboard irradiators have been designed.

On 11th April 1966, an experimental irradiator was built and installed aboard the M.V. *Delaware*. This first shipboard irradiator weighs 15.8 t, stands 2.7 m high and occupies a floor space of about 1.7 m². It contains a 27,000 ci Cobalt-60 plaque in a cask of steel and lead that is 22.8 cm thick, has a dose delivery of about 10 krad/min, and has a throughput of 100 kg of fish products per hour at a dose level of 100 krad.

To date, the unit has been used to radio-pasteurize surf clams (*Spisula solidissima*), haddock (*Melanogrammus aeglefinus*), herring smelt (*Argentina silus*) and codfish (*Gadus morhua*). The shelf life of these products was doubled or tripled. Thus, vessels holding unfrozen fish will now be able to stay at sea for longer periods, increasing the possibility of returning to port with full loads. *Pre-rigor* fish appear to be more suitable for irradiation than *post-rigor* fish are. Otherwise, no quality differences were found. Irradiation at sea can apparently be accomplished with lower dose levels than are necessary in land-based operations.

No problems were experienced in operating the irradiator at sea. This work is being continued.

Irradiation du poisson en mer

Une étude technique a établi que l'irradiation du poisson peut se pratiquer en mer, et plusieurs modèles d'irradiateurs commerciaux de bord ont été conçus. Un appareil expérimental a été construit et installé le 11 avril 1966 à bord du M.V. *Delaware*. Ce premier irradiateur de bord pèse 15,8 t, mesure 2,7 m de hauteur et occupe au sol un espace de 1,7 m². Il renferme une plaque de Cobalt-60 de 27,000 ci dans un caisson d'acier et de plomb de 22,8 cm d'épaisseur. Il peut émettre une dose d'environ 10 krad par minute, et traiter 100 kg/h à 100 krad.

Le groupe a servi jusqu'ici pour la radio-pasteurisation des mactres (*Spisula solidissima*) de l'églefin (*Melanogrammus aeglefinus*), de l'argentine (*Argentina silus*) et de la morue (*Gadus morhua*). La conservabilité de ces produits a été doublée ou triplée, et les navires non congélateurs peuvent maintenant rester en mer plus longtemps, ce qui accroît leurs chances de rentrer au port avec des cales pleines. Il semble que le poisson se prête mieux à l'irradiation avant l'instauration de la *rigor mortis* qu'après. A cette exception près, il n'y a pas de différence de qualité. Selon certains indices, l'irradiation pourrait s'effectuer en mer à des doses plus basses que celles qui se sont révélées nécessaires lors d'essais à terre.

Le fonctionnement de l'irradiateur en mer n'a suscité aucune difficulté. Les travaux se poursuivent.

Irradiación del pescado en el mar

Un estudio técnico ha demostrado que se puede irradiar el pescado en el mar, y se han construido varios irradiadores comerciales para ser instalados a bordo. Se construyó un irradiador experimental que el 11 de abril de 1966 se instaló a bordo de la M.V. *Delaware*: este primer irradiador tiene 15,8 toneladas métricas de peso, 2,6 m de altura y ocupa en el suelo 1,7 m². Dentro de un casco de acero y plomo de 28,8 cm de espesor, contiene una placa de Cobalto-60 de 27.000 Ci con una capacidad de irradiación de 10 krad por minuto y un rendimiento de 100 kg por hora a la dosis de 100 krad.

Este irradiador se ha utilizado, hasta ahora, para radiopasterizar almeja (*Spisula solidissima*), eglefino (*Melanogrammus aeglefinus*), pez plata (*Argentina silus*), y bacalao (*Gadus morhua*). Se consiguió duplicar o triplicar la duración en almacén de estos productos, de forma que los buques que transportan pescado sin congelar pueden permanecer en el mar durante períodos más largos, aumentando la probabilidad se regresar al puerto con plena carga. El pescado en estado de "*pre-rigor*" parece que se presta mejor a la irradiación que en estado de "*post-rigor*"; por lo demás. no hay diferencias de calidad. Se han obtenido algunas pruebas que demuestran que la irradiación en el mar requiere dosis inferiores que las que fueron necesarias en los experimentos efectuados en tierra.

El funcionamiento del irradiador en el mar no ha planteado ningún problema. Esta investigación continúa.

WORK on the irradiation of fish at sea is being carried out by the Bureau of Commercial Fisheries Technological Laboratory in Gloucester, Massachusetts, under a contract with the United States Atomic Energy Commission.

Our work on the feasibility of radiopasteurizing seafoods indicated early that this process could be used to extend the market life of fresh fish landed in our ports (Slavin, Steinberg and Connors, 1963). In addition, it indicated that the better the quality of the fish at the time of irradiation, the better the quality and the longer the refrigerator storage-life of the treated fish (Slavin and Ronsivalli, 1963). This relation was probably due to the degree of bacterial contamination, which would be relatively light in freshly-caught fish and would become greater as the fish approaches the point of spoilage during storage. Evidently, the best time to irradiate fish for extending storage life and retaining quality maximally would be immediately after the capture of the fish, when the bacterial load would be at its lowest point. Since the purpose of irradiation is to reduce the number of bacteria, it was expected that pasteurization aboard the vessel could be effected with relatively low doses of irradiation.

Thus, this work was begun primarily to determine whether or not it is actually advantageous, from the standpoint of product, economics and quality to radiopasteurize fishery products at sea.

The shipboard irradiator

Prior to the start of this work, a separate engineering study was conducted by the Vitro Engineering Company of New York City to determine whether or not it is physically possible to equip a trawler with an irradiator (Armel and Manowitz, 1963). This study showed that a conventional trawler that is 45.8 to 55 m in length (150 to 180 ft) could be designed to house a Cobalt-60 irradiator with a throughput capacity of 3,400 kg of fish products per hour (7,500 lb/h) at a dose rate of 75 to 150 krad. The Vitro report also pointed out that many of the U.S. boats return to port with a catch equal only to about 30 per cent of their maximum carrying capacity because fish spoil so rapidly and that even with shortened trips, the catch oftentimes is of dubious quality. A separate study has shown that as much as 15 per cent of the catch landed in some of our ports is of subquality

(Kaylor, 1965). An irradiator would easily fit into the trawler and enable it to stay out longer to fill its holds and yet bring in fish of high quality.

Once determined that it was physically possible to house a Cobalt-60 irradiator aboard a trawler, it was decided to conduct pilot experiments with a small experimental irradiator. Personnel at the High Intensity Radiation Laboratory at the Brookhaven National Laboratory in Upton, Long Island, New York, designed a small, pilot-plant-type irradiator that could be mounted within a hold or on the deck of a trawler. Three such irradiators were built at a cost of about $40,000 each. On 11th April 1966, the first of these was installed aboard the Bureau's research vessel, M.V. *Delaware*.

Physically, this irradiator, as shown in fig 1, weighs 15.8 t (17.5 s. t), stands 2.7 m high (8 ft 10 in) and occupies a floor space of 1.2 × 1.4 m (47 × 55 in). Essentially, it is made up of two parts—the cask and the collar assemblies. The cask assembly consists of a lead-filled, double-walled, stainless-steel shell 22.8 cm (9 in) thick and provides the primary shielding for the 27,000 ci Cobalt-60 source plaque. This plaque is mounted securely athwart-ships within the cask and is not movable. On the fore and aft sides of the plaque are two lead-filled stainless-steel package carriers or shuttles that move up and down a distance of about 64 cm (25 in) within guides. The cask also contains about 39.5 m (130 ft) of 1.27 cm (½ in) monel tubing encased in the lead fill for use in irradiating sea-water.

Bolted tightly to the top of the cask is the collar assembly. It contains guides aligned with those in the cask for guiding the shuttles in their upward and downward travel, a motorized hoist for lifting and lowering the shuttles, operating controls, auxiliary shielding, and an adapter for mounting the package loader.

Tests for radiation leaks showed that the shielding reduced the radiation field around the irradiator down to the safe working level of less than 2 mrad/h.

For irradiation, the samples are placed in a stainless-steel sample box, the box is loaded into the nearest shuttle and the shuttle is lowered to the point where the box is directly next to the cobalt plaque. To minimize differences in the dose distribution, the operator lowers each sample box to the cobalt twice, once in each shuttle chamber. Thus, the box is irradiated once on each of its two broad sides. A loading device aids in the loading and unloading of the sample boxes, thereby allowing the operator to keep his hands out from under the heavy shielding [362 kg (800 lb)] and away from any stray gamma rays around the shuttle.

Dosimetry of the shipboard irradiator

Before the irradiator was installed aboard the M.V. *Delaware*, it was delivered to the laboratory to permit dosimetry studies and to enable the operators to familiarize themselves with it. Dosimetry studies were conducted with rice, water and codfish matrices. Ten to 15 aqueous ferrous sulfate-cupric sulfate dosimeters were distributed as evenly as possible through each of the matrices. Results of the dosimetry studies indicated that the irradiator was capable of delivering a dose rate of about 10 krad/min. Maximum/minimum dosage ratios were quite low; they ranged from 1.11 in codfish to 1.40 in rice.

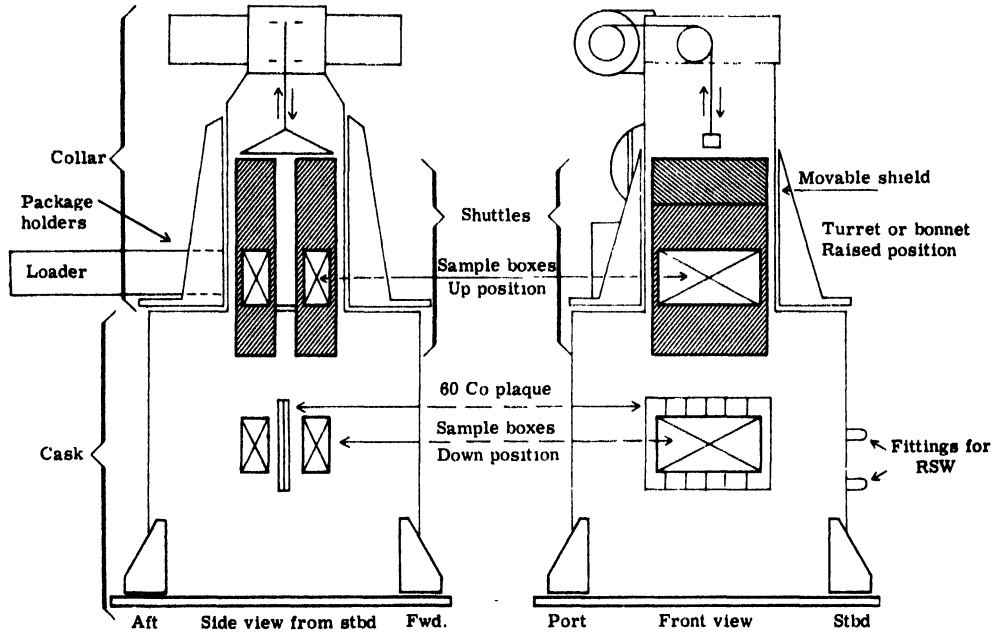


Fig 1. Cut-away view of the shipboard irradiator

Installation of the shipboard irradiator

On 11th April 1966, the irradiator was mounted in the no. 3 hold of the M.V. *Delaware* in accordance with a design (fig 2) engineered by the naval architect employed. It was bolted to a base consisting of four steel H beams

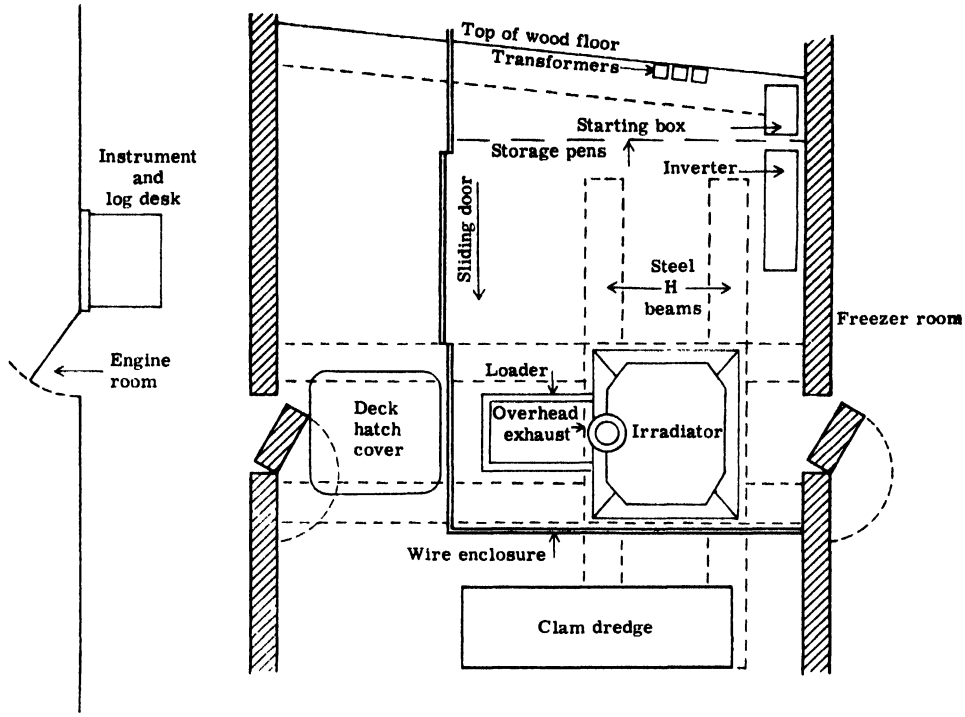


Fig 2. Layout of the number 3 (irradiator) hold aboard M.V. Delaware *(top view)*

set in a bed of concrete. This mounting was constructed so that it was strong enough to support twice the weight of the irradiator safely during the most severe weather conditions. Installation costs totalled $19,000, which included the preparation of the concrete-steel bed, ancillary electric equipment, a wire-mesh enclosure to isolate the irradiator from the crew, the installation of the irradiator, and all labour costs.

At sea, the irradiator performed satisfactorily at all times—even in rough weather, when the boat rolled through angles of up to 24° to 27°. It is doubtful that fishing operations can safely continue when this range of angles is exceeded. Hence, the irradiator can be operated during any normal fishing operation.

EXPERIMENTAL

With respect to the irradiation of fishery products, three simulated shipboard irradiator experiments were conducted on land, and five experiments were conducted at sea. For the experiments on land, live codfish (*Gadus morhua*), from our tanks were used. In the first two of these experiments, the codfish were irradiated at the Laboratory's Marine Products Development Irradiator (MPDI), which employs a 0.25 Mci Cobalt-60 source, and the third experiment was conducted with the shipboard irradiator while it was housed in the Laboratory. The remaining experiments—three on haddock (*Melanogrammus aeglefinus*), one on herring smelt (*Argentina silus*), and one on surf clams (*Spisula solidissima*)—were conducted with the shipboard irradiator at sea. In each experiment, the samples were first packaged in plastic bags before being loaded into the sample carrier boxes. The samples were packaged to protect them from recontamination during storage and to keep the irradiator clean. Fish irradiated in the *pre-rigor* state were processed immediately after they were taken from our tanks or after they were caught at sea. Those fish irradiated in the *post-rigor* state were stored on ice for about 24 h to allow for the passage of *rigor*. Once irradiated, the fish, in bags, were stored either packed in ice or were held in air at 0.6°C (33°F) except the surf clams, which were held frozen aboard the M.V. *Delaware* because of a lack of ice during the trip in which they were tested. They were thawed upon return to port and stored at 0.6°C (33°F).

About seven to 10 days after being irradiated initially, some of the treated fish was re-irradiated. Thereafter, all treated products were periodically evaluated, after being steam cooked, in order to determine their storage life at 0.6°C (33°F). The rationale for these tests are given in a paper by Ampola and Ronsivalli (1967).

RESULTS AND DISCUSSION

Results of these evaluations are summarized in table 1. The iced, non-irradiated haddock and herring smelt each had an exceptionally long usable storage life. This long life is attributable to the fact that they were kept well iced throughout the period of storage. Even so, by irradiation, the average shelf life at 0.6°C (33°F) of codfish was increased by 50 to 150 per cent, of haddock by 33 to 78 per cent, of herring smelt by about 40 per cent, and of clams by 350 to 490 per cent.

The effect of the state of *rigor* is not clear from table 1. However, when the data were treated statistically, the *pre-rigor* fish appeared to be more suitable for the

TABLE 1. AVERAGES OF THE ACCEPTABLE 0.6°C (33°F) STORAGE LIVES OF FISH IRRADIATED IN THE SHIPBOARD IRRADIATOR STUDIES

Species	*State of* rigor	*Dosage (krad)*		*Average acceptable storage life at 0.6°C (33°F) (days)*
		Shipboard irradiator	*MPDI*	
Codfish (*Gadus morhua*)	*Pre-*	100	0	32
		100	100	32
		0	0	14
	Post-	100	0	21
		100	100	35
Haddock (*Melanogrammus aeglefinus*)	*Pre-*	50	0	24
		50	100	32
		150	0	24
		150	100	25
		0	0	18
	Post-	50	0	28
		50	100	25
		150	0	29
		150	100	29
Herring smelt (*Argentina silus*)	*Pre-*	0	0	15
		50	0	21
		50	100	21
		100	0	21
Surf clams (*Spisula solidissima*)	*Pre-*	0	0	10 estimated
		100	0	35
		100	350	49
		200	0	35
		450	0	49

irradiation process than were *post-rigor* fish. Usually, the fish irradiated in the *pre-rigor* state were judged by our panel to be more acceptable during the first few weeks of storage than were fish irradiated *post-rigor*. This is reasonable in as much as irradiation tends to stabilize the quality of the product at the time of processing. Thus, those fish irradiated in the *pre-rigor* state tended to have their quality stabilized to what it was immediately after catching and those irradiated in the *post-rigor* state to the quality level of one-day iced fish. Also, in consideration of bacterial numbers, it is highly probable that the bacterial population at the time of irradiation was considerably lower in the *pre-rigor* fish than in the *post-rigor* fish. Then, since the rate of bacterial destruction is fairly constant for a given dosage level, there were probably a greater number of surviving bacteria in the *post-rigor* fish after irradiation to contribute toward spoilage. After a few weeks of storage, however, the *pre-rigor* irradiated fish lost quality more rapidly and approached the quality of the *post-rigor* irradiated fish. At this time, we have no explanation for this phenomenon.

With respect to the effect of re-irradiation, an additional radiopasteurization dose after about a week of iced storage helped to extend further the storage life of some of the treated products. This is because the additional radiopasteurization dose reduced the total aerobic bacterial population at the time of reprocessing. Moreover, the low doses used did not induce any off odours or flavours and thus did not affect the quality of the fish. This finding is important in consideration of the possible bacterial contamination of the irradiated fish—for example, as a result of a filleting operation.

Where possible, total plate counts for aerobes were made at the laboratory. Because of a lack of facilities aboard the M.V. *Delaware*, no bacteriological work was done at sea. Generally, the results of these analyses indicated that irradiation significantly reduced the initial aerobic population and that, with increasing storage time, fish became spoiled when the counts reached 10^6 to 10^7 per 6.45 cm^2 (1 in^2). This finding is generally true also of non-irradiated fish and of fish irradiated at the MPDI.

The dosage level of 50 krad apparently was just as effective in extending the shelf life of the treated fish as were the dosage levels of 100 and 150 krad. Previous data (Slavin and Ronsivalli, 1963), on fish one to two days out of the water showed that a dosage level of 50 krad was not as effective in prolonging the storage life of fish as were dosage levels of 150 krad and more. Thus, lower radiopasteurization dosages apparently can be used effectively at sea. This difference is due to the fact that the bacterial load on a freshly-caught fish is probably quite low and that a dose of 50 krad at sea would probably reduce this load to the same level as a dose of 150 krad on a fish one to two days out of the water.

When these data are compared with similar data developed on one- to 15-day iced fish that had been irradiated at the MPDI, it is noted that the shelf life of those fish irradiated at sea is similar to the shelf life of those fish that had been held on ice for up to about nine days prior to radiopasteurization. Therefore, considering only the potential extension in shelf life, we might conclude that there was no advantage to irradiating fish at sea. However, the irradiated fish, as landed, was of excellent quality even when iced up to 10 days. Their quality was comparable with that of one to two-day old fish. The fish irradiated in the *pre-rigor* condition appeared to be more acceptable than those irradiated in the *post-rigor* condition and, as aforementioned, this is probably because irradiation tends to stabilize the quality level of the product to what it was at the time of processing.

Thus, irradiation at sea does offer the potential of

landing fresh fish of higher quality than is now being landed. Also, since levels of re-irradiation do not adversely affect the quality of radiopasteurized fish, additional radiopasteurization can be used to stabilize the quality of the fish after they are processed ashore into fillets and other market forms. A realization of these potentials would greatly increase the quality of fish as landed and marketed—thus eliminating the presently occurring losses due to poor quality. Irradiation at sea also offers the potential of allowing the boats to stay at sea longer to fill their holds because of the superior storage characteristics of radiopasteurized fish. Lastly, less of a radiopasteurization dose apparently is needed at sea than on land in order to attain an appreciable extension in shelf life of the treated fish.

References

AMPOLA, V G and RONSIVALLI, L J 1967 Effect of pre-irradiation quality of eviscerated haddock on the post-irradiation shelf life of the fillets. (MS.)

ARMEL, J and MANOWITZ, B 1963 Study Report. Shipboard ^{60}Co radiopasteurizer for marine products. *Brookhaven National Laboratory, BNL 808* (T-311).

KAYLOR, J D 1965 Private communication on the incomplete results of a cap-log survey concerning the quality of fish as landed.

SLAVIN, J W and RONSIVALLI, L J 1963 *Rep. Congr. atom. Energy Commn U.S.*, TID-19969.

SLAVIN, J W, STEINBERG, M A and CONNORS, T J 1963 *Rep. Congr. atom. Energy Commn U.S.*, TID-18285.

Meat Colour Regeneration in Frozen Tuna by Irradiation

by K. Amano and H. Yamanaka

Meat colour regeneration in frozen tuna by irradiation

In spite of many efforts in the handling aboard, discolouration of frozen tuna is unavoidable and causes unprofitable market price for the fish handlers who can find out the defect only after thawing.

A known action of gamma irradiation to convert metmyoglobin to oxymyoglobin was examined as to the improvement of meat colour of frozen tuna. Between 0.2 and 1 Mrad of given dosages, the grade of colour regeneration in terms of metmyoglobin percentage was 37 to 39 per cent after irradiation of a discoloured tuna containing 75 per cent of metmyoglobin and these were judged bright red organoleptically. However, irradiation higher than 0.2 Mrad was found not practical, because of the developed off-flavour.

More important problem noticed was reversible formation of metmyoglobin in comparatively short time even under freezing condition. Further studies shall be needed to prolong the regenerated meat colour.

Recoloration par irradiation de la chair de thon congelé

En dépit des soins apportés à la manipulation du poisson à bord, il est impossible d'éviter la décoloration de la chair du thon congelé. Ce défaut n'apparaissant qu'après la décongélation, c'est le transformateur qui en souffre.

On sait que l'irradiation aux rayons gamma convertit en oxymyoglobine la metmyoglobine de la chair du thon congelé, ce qui fait réapparaître le rouge vif des tissus qui avaient bruni.

Les doses de radiation employées allaient de 0,2 à 1 Mrad. La recoloration obtenue a varié entre 37 et 39 pour cent pour une couleur initiale correspondant à 75 pour cent de metmyoglobine. La brillance du rouge a été évaluée en conséquence, mais l'on a jugé qu'il convenait de ne pas dépasser la dose de 0,2 Mrad, au-delà de laquelle apparaissait une saveur indésirable.

Malheureusement, la réaction est réversible même sous congélation. De nouveaux travaux seront nécessaires pour découvrir un moyen de prolonger cette recoloration de la chair du poisson.

Regeneración por irradiación del color de la carne de atún congelado

A pesar de todos los esfuerzos que se hacen en la manipulación a bordo de los barcos es inevitable el cambio de color del atún congelado. Esto supone un inconveniente para el industrial elaborador que encuentra este defecto tan solo después de efectuada la descongelación.

Se sabe que la irradiación con rayos gamma convierte la metamioglobina en oximioglobina en la carne de atún congelado haciendo que el color oscuro adquirido se convierta de nuevo en un rojo brillante.

Se emplean dosis de 0,2 a 1 Mrad. La gama del color regenerado fue de 37–39 por ciento a partir de un color original del 75 por ciento de metamioglobina. De acuerdo con ello se juzgó la brillantez del rojo, pero las dosis superiores a 0,2 Mrad se hallaron impracticables debido a la adquisición de sabor desagradable.

Fue desanimador observar que la reacción era reversible incluso en condiciones de congelación. Será preciso realizar otros estudios para encontrar el modo de prolongar el color de la carne regenerada.

IT is well known that meat irradiated in atmosphere undergoes a remarkable discolouration by forming metmyoglobin. But, on the other hand, regeneration of oxymyoglobin from metmyoglobin by irradiation has also been noticed by many investigators in various kinds of meat. Tappel (1956) proposed a mechanism of regeneration by the action of hydroxyl radicals formed by the ionization of water by gamma radiation. Matsuura and colleagues (1966) examined the changes of tuna myoglobin preparations induced by irradiation and observed that pigment concentration, and pH and salt concentrations would be the factors to accelerate the changes.

The writers presumed that the regeneration of oxymyoglobin of this type might find a practical application for the colour improvement of frozen tuna, since the industry has been seeking some technological solution for the discolouration. As there has been no information available about quantitative evaluation on the regeneration of oxymyoglobin by the irradiation, the present paper reports a preliminary part of the observations on the dose levels required to attain a desirable generation and its possible period of retention of the colour in frozen storage.

EXPERIMENTS

Materials and methods

A fillet of big-eye tuna (*Parathunnus sibi* T. and S.), caught and frozen on board about one month ago in the Indian Ocean was assessed for its metmyoglobin level prior to the experiment, and was then dissected into pieces $5 \times 25 \times 1$ cm. Each cut was placed in a bag of cellophane-polyethylene or aluminium-polyethylene laminates and sealed in a vacuum. Irradiation was carried out on these samples at $-10°C$ ($+14°F$) from a ^{60}Co source with 1,400 ci, by giving dosages of 1, 0.5, 0.2 and 0.1 Mrad respectively. After irradiation, these were stored in a freezer at $-20°C$ ($-4°F$) and the change in the concentration of metmyoglobin was determined by the method described by Bito (1965) based on the absorbance ratio at 503 mμ and 540 mμ of aqueous extract of tuna meat.

Organoleptic examinations of the irradiated tuna meat were determined after defrosting at each stage. Electrophoretic pattern using starch gel medium by Yamanaka, Yamaguchi and Matsuura (1965) was observed on both an aqueous extract and cyanmetmyoglobin preparations from the samples irradiated at 1 and 0.5 Mrad. Cyanmetmyoglobin was prepared by the addition of potassium ferricyanide and potassium cyanide to an aqueous extract of irradiated or unirradiated tuna flesh.

RESULTS AND DISCUSSION

Meat colour development and dosage

As described in table 1, the meat colour developed in proportion to the given dosages (fig 1). Irradiation of 3 and 1 Mrad revealed a satisfactory colour of bright red, but the samples were not acceptable on account of their off-flavour and odour. Disagreeable flavour was readily

Fig 1. The effect of different dosage of irradiation on the colour regeneration of tuna meat. Photograph was taken after the sample meat had been defrosted

[Facing page 514

TABLE 1. GRADE OF MEAT COLOUR DEVELOPMENT AND EATING QUALITY OF THE IRRADIATED FLESH OF BIG-EYE TUNA (*Parathunnus sibi* T. AND S.) BY ORGANOLEPTIC RATING

Dosage (Mrad)	*Grade of meat colour*	*Flavour acceptance*
3.0	Brightest red	Not acceptable
1.0	Brightest red	Not acceptable
0.5	Bright red	Tolerably acceptable
0.2	Bright red	Acceptable
0.1	Red	Acceptable
0.05	Slightly pink	Acceptable
0	Tan	Acceptable

Examinations were performed by the experienced tuna handlers from Tokyo Central Wholesale Market and the laboratory personnel.

perceived even in the sample treated at 0.5 Mrad. The maximum tolerable dose from a standpoint of the eating quality of irradiated tuna was probably 0.2 Mrad.

Meat colour regenerates in frozen tuna whether it is sealed in the packaging films or not. However, the presence of air at the time of irradiation counteracts the colour regeneration. The colour development has been most remarkable in the tuna meat vacuum-sealed in aluminium-polyethylene packages, possibly due to its less permeable property.

Retention of the regenerated meat colour

It was noticed that the regenerated meat colour faded again by a reversible formation of metmyoglobin. The reversion from the regenerated oxymyoglobin to metmyoglobin in the differently packaged samples of irradiated meat stored at −20°C (−4°F) for a period of 168 h was examined. Increase in the metmyoglobin concentration is shown in figs 2, 3 and 4. The reversion is most rapid in the samples irradiated and stored without packaging material.

Figure 5 indicates the influence of the permeability of packaging material on the reversion rate of metmyoglobin during the frozen storage of tuna meat after irradiation at 0.2 Mrad while under refrigeration. It is clear from these findings that frozen storage does not arrest the reversion of oxymyoglobin to metmyoglobin and so the elimination of air (oxygen) is a prerequisite to the meat colour retention. However, a better retention of the meat colour may be expected if the storage temperature of the irradiated meat of tuna is lowered to −35°C (−31°F) (Bito, 1965).

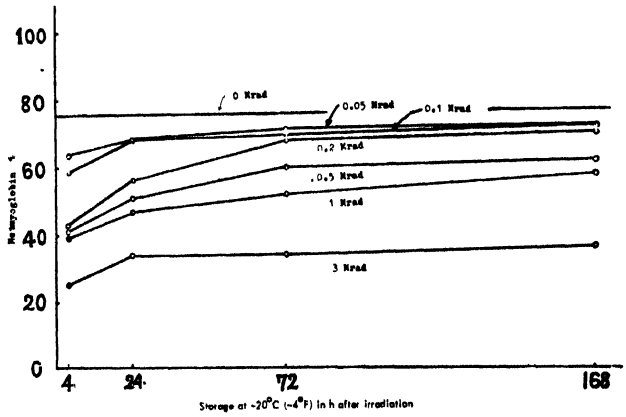


Fig 2. Reversion of metmyoglobin in frozen tuna irradiated without packaging

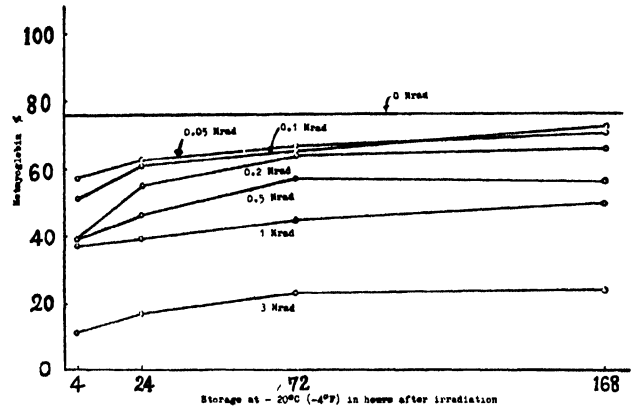


Fig 3. Reversion of metmyoglobin in frozen tuna irradiated after vacuum sealing in cellophane-polyethylene film package

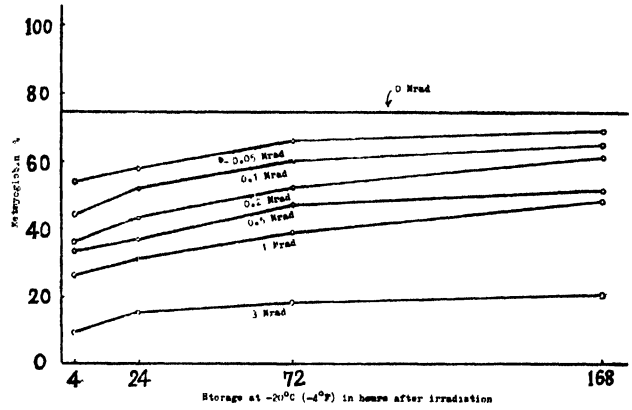


Fig 4. Reversion of metmyoglobin in frozen tuna irradiated after vacuum sealing in aluminium-polyethylene film package

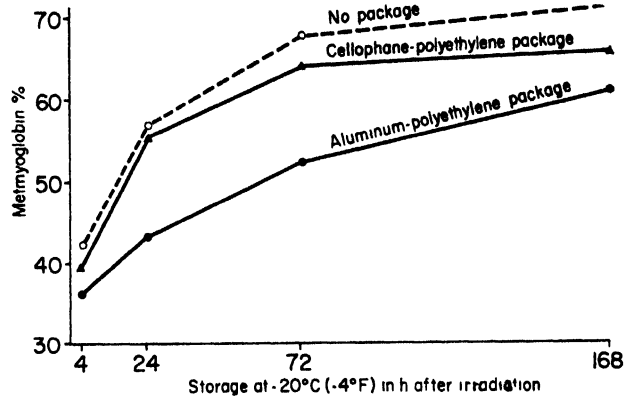


Fig 5. Effect of permeable and less permeable packages on the reversion rate of metmyoglobin in frozen tuna meat irradiated at 0.2 Mrad

Electrophoresis of aqueous extract and of cyanmetmyoglobin prepared from the irradiated tuna meat

Aqueous extracts of the irradiated and unirradiated tuna meat, as well as cyanmetmyoglobin prepared from myoglobin fraction, showed none of the differences on their electrophoretic patterns. Dosages less than 1 Mrad may not cause any drastic change in these proteins.

A possible occurrence of reduced form of myoglobin by irradiation

It is quite obvious that bright red colouration occurring in the irradiated tuna meat is due to the regeneration of oxymyoglobin. An example of the change in the absorption spectrum of aqueous extract of frozen big-eye tuna before and after irradiation at 0.4 Mrad shown in fig 6, indicates the characteristic absorption maxima of oxymyoglobin at 540 mμ and 576 mμ for the extract of the irradiated fish.

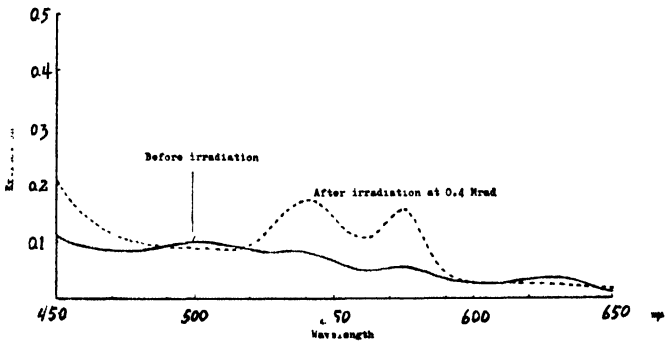


Fig 6. Absorption spectra of aqueous extract of frozen meat of big-eye tuna before and after irradiation at 0.4 Mrad

Meanwhile, it has frequently been observed that tuna meat is purple-red in colour immediately after irradiation with comparatively high doses and that this colour turns to a bright red on removal of cellophane-polyethylene film package. But this does not necessarily mean that the exposure to atmosphere is required for the colour development, because the regeneration can be observed through the transparent wrappings immediately after the irradiation.

It will be of interest if further reduction of oxymyoglobin can take place during the irradiation. Using opal glass technique, the irradiated tuna meat was directly subjected to spectrophotometric examination to determine whether reduced form of myoglobin was existing together with oxymyoglobin. However, it was not possible to demonstrate the occurrence of reduced myoglobin, probably because a swift alteration of purple colour did not permit enough time to take a spectrum.

SUMMARY

The effect of regeneration of oxymyoglobin by irradiation was examined on frozen big-eye tuna meat which contained 75 per cent metmyoglobin. A satisfactory colour regeneration concurrent with no off-flavour was produced by using a dosage 0.2 Mrad.

The colour was only transitory, however, and more studies will be required to determine how to stabilize this regenerated colour.

Acknowledgment

The writers wish to thank Prof. F. Matsuura of the University of Tokyo for his valuable suggestions.

References

BITO, M *Bull. Jap. Soc. Scient. Fish.*, **31**, 534. 1965

MATSUURA, F Personal communication. 1966

TAPPEL, A L *Fd Res.*, **21**, 650. 1956

YAMANAKA, H, YAMAGUCHI, K and MATSUURA, F *Bull. Jap. Soc. scient. Fish.*, **31**, 827. 1965

DISCUSSION

Wiesner and Walther (Federal Republic of Germany): Apart from refrigeration methods irradiation treatments may also contribute to the extension of the fish market. Some day radiosterilization may compete with refrigeration but, for the moment, radiosterilization of fish cannot be proposed as technically feasible because of the high doses which have to be applied; the application of several Mrad would result in very high treatment costs and would also result in severe restrictions from the biological point of view. However, radiopasteurization which can be performed with doses in the order of 100 krad can extend the shelf life of wet fish considerably as many investigations especially in the United States, have demonstrated.

The wet fish market, e.g. in the Federal Republic of Germany, has a considerable potential, if the good quality of the products can always be guaranteed. Under actual conditions, this is not always possible. To offer the customer at least really acceptable products, the first fish caught during a voyage determines for the vessel the time of return into the harbour. The consequence is that vessels have often to return home when they have caught a quantity of fish corresponding only to 40, 50 or 60 per cent of their loading capacity. Radiopasteurization, performed on board within the period from several hours up to about one day after the fish has been caught, will prolong the shelf life so much that, in most cases, vessels may remain on the fishing grounds until fully loaded. On the other hand, the average quality of the product which reaches the consumer will be considerably better.

Recent investigations have shown that a first irradiation with only about 50 krad, immediately after the fish has been caught, is sufficient to extend the shelf life in the order of 10 days for some important species. A further extension can be achieved later on, by a second irradiation in a shore-based plant with another dose of about 50 krad.

Under these aspects, plants for radiopasteurization aboard ship have been developed as well as shore-based plants for the same purpose. This has been done with specific reference to the situation in the Federal Republic of Germany.

Irradiation plants on board fishing vessels should fulfil the following conditions.

In the first place the throughput should be of the order of 1 to 2 t of fish per hour which would correspond to the quantity of fish in large sets and the normal time interval between two sets.

Secondly, the dimensions and the weight of the irradiation facility should be fairly small. The condition of minimum weight lead to the selection of the radioisotope Cesium-137 instead of Cobalt-60, generally preferred up to the present as radiation source.

^{137}Cs emits a gamma radiation of 0.66 MeV while ^{60}Co disintegrates with the emission of more energetic gamma rays (1.17 and 1.33 MeV).

In materials consisting mainly of light elements, as fish, the radiation energy emitted by these two isotopes is absorbed by a given quantity of material to about the same amount. However, the radiation of ^{137}Cs is absorbed twice as effectively by heavy elements as the gamma rays of ^{60}Co. In effect only 2.1 cm lead are necessary to reduce the radiation intensity in the case of ^{137}Cs to one tenth of its original value, while in the case of ^{60}Co, 4 cm lead are necessary to result in the same effect.

This means that a shipboard ^{137}Cs irradiation plant will have only about half the weight of a comparable ^{60}Co facility. To install the same irradiation capacity, the somewhat higher investments still required for ^{137}Cs as compared to ^{60}Co are already largely offset by the lower costs of the shielding. Moreover, ^{137}Cs prices will probably decline more rapidly than prices for ^{60}Co in the near future.

It should also be mentioned that the half-life of ^{137}Cs of about 30 years necessitates an annual replenishment of only 2.2 per cent of the installed activity against an annual rate of 12.5 per cent for ^{60}Co which has a half-life of only about five years.

The weight of ^{137}Cs plant for the treatment of 1 to 2 t/h with a dose of 50 to 100 krad will be in the order of 30 t, the dimensions of the facility are roughly $2.5 \times 2 \times 1.5$ m ($8 \times 6.5 \times 5$ ft).

Thirdly, the labour requirements for the extra handling of the fish passing the irradiation plant should be as small as possible. The irradiation plant itself does not require any operational activity during irradiation except for the switching of the conveyor, the speed of which has to be in accordance with the required dose. For the handling of the fish in connection with the radiation treatment, several technical solutions are possible. In one of the designs elaborated for shipboard irradiation plants and illustrated in fig 1, the fish is transported in such a way through the irradiation chamber as a quasi-continuous stream that the irradiation process becomes an integral part of the product flow between the working area and the storage room.

Finally, the ratio of maximum to minimum doses in the irradiated fish should be minimized. By the absorption of radiation in irradiated goods, a certain non-homogeneity of the dose is always caused. The thickness of the goods which the radiation has to penetrate must, therefore, be limited in accordance with the absorption characteristics.

In order to irradiate rather thick layers of fish with a good degree of homogeneity, provision has to be made for its irradiation from at least two sides. With the design shown in fig 1, this is achieved by rotation of the casks, which serve as containers for the fish inside the irradiation chamber.

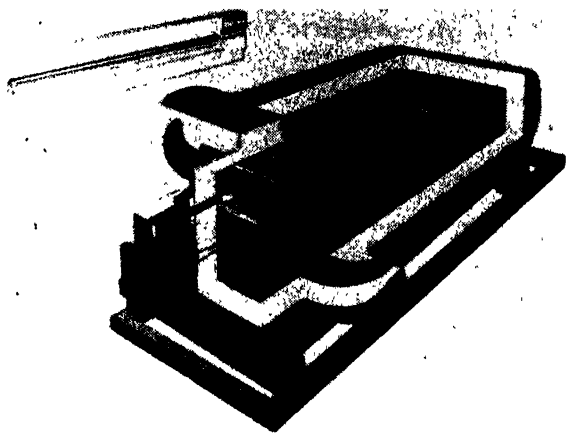


Fig 1. Cut-away sketch of shipboard irradiator

Other factors influencing the dose distribution inside irradiated goods (configuration of the radiation sources and of the conveyor system) will not be discussed here.

By a proper selection of all these parameters, it is possible to obtain an efficiency for the utilization of the produced radiation energy of between 30 and 40 per cent, even with shipboard irradiation facilities.

For a dose of 50 krad, the residence time of a fish inside the irradiation chamber is about 15 to 20 min and for higher doses correspondingly longer.

The foregoing description of the main design principles for shipboard irradiation plants demonstrates that such facilities are technically quite feasible for sea-going fishing vessels. Shipbuilders have confirmed that the plants can be installed, for example, in the upper part of the fish-rooms of vessels already in service, as illustrated by fig 2.

Shore-based facilities for the radiopasteurization of fish have to meet less specific requirements than shipboard plants. The following may be mentioned among the considerations which were taken into account in the development of the facility shown in fig 3.

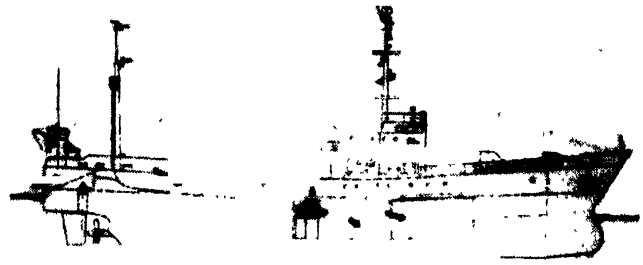


Fig 2. Sketch illustrating installation of shipboard irradiator

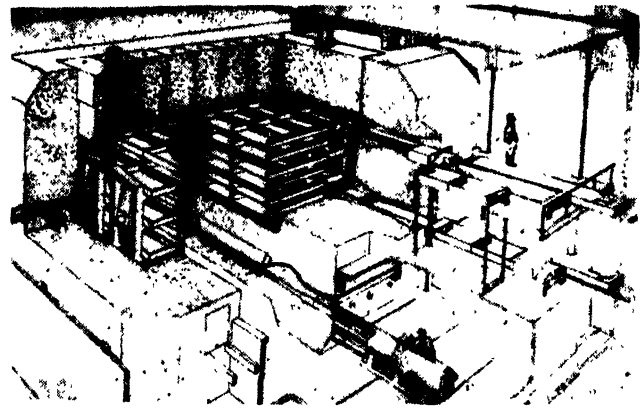


Fig 3. Sketch of land-based irradiator

In this case, a high degree of utilization of the radiation energy produced is of much greater importance. Since there are virtually no space limitations, the automatic conveyor system for irradiation of fish and fish products can be laid out in such a way that an efficiency of more than 40 per cent is obtained.

Shore-based fish irradiation plants should have a throughput of at least several tons of fish and fish products per hour. Since the irradiation costs decrease with increasing irradiation capacity, the collaboration of several fish industries in the same port in the operation of one irradiation plant is highly desirable from an economic point of view.

The weight and the dimensions of the radiation shielding are much less important than in the case of shipboard irradiators; therefore, the main reason for preferring ^{137}Cs against ^{60}Co does not exist. One might choose ^{60}Co on the

basis of actual price levels but it should be ensured that later on ^{137}Cs could be used in the same plant when it becomes cheaper. Anyway, the configuration and construction of the source should be such that maximum versatility is assured, with the possibility of a later increase of the irradiation capacity according to the development of the market and for the easy and economical replenishment of the source.

A detailed and precise economic analysis of the radiopasteurization process can only be given for a specified set of conditions (irradiation dose, throughput, handling system, etc.). The following discussion based on typical requirements will, however, illustrate that the radiopasteurization of fish and fish products is economically very attractive (table 1).

A shipboard irradiation plant for the treatment of 2 t/h with 50 krad like the one shown in fig 1 will require investments in the order of DM500.000. The radioactive source accounts for more than 50 per cent of this price, the installation on board a new or already existing vessel for another 5 per cent or less, while the rest must be spent for the shielding, the conveyor system and other auxiliary parts of the plant.

TABLE 1. ESTIMATE COSTS OF IRRADIATION OF FISH AT SEA AND ON SHORE

	Shipboard plant	*Land-based plant*
Dose	50 krad	50 krad
Annual throughput	8,500 t	27,500 t
Annual running time	177 days	230 days
Total investments	DM500,000	DM1,200,000
Annual expenses	DM85,000	DM275,000
Costs of irradiation	DM0.01/kg	DM0.01/kg

As compared with the annual capital services, amounting to 15 per cent of the total investments (8 per cent amortization, 7 per cent interests) the annual operational costs are negligible: DM7,000 for the replenishment of the ^{137}Cs source, and DM3,000 for the consumption of electrical energy by the conveyor system and for servicing regularly the facility.

It can be assumed that the irradiation facility will be utilized about 4,250 h (177 days) per year, taking into account the time during which the vessel is in port, travelling to the fishing grounds, searching for fish and in unfavourable weather conditions.

Under this assumption, the 8,500 t, annually pasteurized with 50 krad, have to pay for the expenses of DM85,000. Thus, the pasteurization with 50 krad costs only 0.01 DM/kg. This price, however, does not include the additional labour requirements on board for the radiation treatment of the fish, and other investments which may be necessary for protecting the fish against a rapid reinfection. Sufficient cleanliness of the storage room can probably be achieved with rather moderate efforts.

For shore-based irradiation facilities the cost of the pasteurization is calculated for a plant having a throughput of 5 t/h to be irradiated with 50 krad. Such a facility would require the investment of about DM1,200,000. If ^{60}Co is used as radioactive material the source would account for some 40 per cent of the total investments, the plant itself including the shielding and the conveyor system for another 40 per cent, while the rest is required for general installations and for storage rooms in which treated and untreated fish and fish products are stored separately.

Assuming amortization in this case within 10 years and 7 per cent as rate of interest, the annual capital services amount to DM204,000. The replenishment of the installed radioactive material will amount to about DM65,000 per year. The DM6,000 per year for the electric energy, consumed by the conveyor system, and for servicing the facility regularly, finally bring up the annual expenses to a total of DM275,000.

For a shore-based fish irradiation plant, 230 days per year (about 5,500 h) operation at full load seems to be quite reasonable. In this case, 27,500 t could be pasteurized with 50 krad. Again a cost of 0.01 DM/kg is incurred for the irradiation treatment. This price does not include handling costs of the fish or fish products, which might be appreciable in this case. Even if the procedure of loading and unloading the irradiation boxes can be highly automated with some additional investments, at least one person should always be present on account of the safety regulations.

It may be surprising that the same cost of radiation treatment is incurred by the larger shore-based plant and the smaller shipboard facility. This is mainly due to two factors. In the case of a shipboard irradiator, its housing necessarily already exists, while for the shore-based plant some other building apart from the radiation-shielding will be necessary. Storage rooms, an office, a more expensive and sophisticated conveyor system have necessarily to be added to a shore-based plant.

For the shipboard irradiator, an amortization period of 12.5 years was assumed because this same period is, at least in Germany, also applied to the whole fishing vessel. The shore-based plant was calculated with amortization within only 10 years. These factors increase the cost of the radiation treatment in a shore-based plant by about 40 per cent, as if it were calculated under the same conditions valid for the shipboard facilities.

In conclusion, I think it has been shown that the radiopasteurization of fish and fish products is not only technically feasible on account of the simplicity of irradiation plants, easy to install on board fishing vessels, but also highly economical, even if larger doses than 50 or 100 krad for the pasteurization should be required. The low cost of radiopasteurization has to be compared with advantages in the better utilization of the fishing vessels and in the possibility of selling a larger portion of the catch as high quality wet fish instead of selling it to the fish meal industry.

The importance of this process not only for the fishing industry itself, but also for the national economy of countries with a large market for wet fish, is quite obvious.

Amano (Japan): In Japan, where about 2 million tons of frozen fish are produced and transportation distances for fresh iced fish are not great, the industry's interest in the irradiation preservation of fish is not very high. I would like to know the opinion of the industry on the future commercial possibilities for irradiated fish in European countries, the United States and other areas where interest is shown in this new way of preservation.

Rudolphi (Federal Republic of Germany): The industry looks forward to this new process with great interest. From the German situation we should be quite satisfied if there could be a shelf life gain of 10 to 14 days. This would be sufficient to recover lost territory on the market for fresh fish.

Liston (U.S.A.): This is interesting because it shows the logistics of utilization of radiation. When long distance transport on land is involved, it becomes particularly useful and this, I suspect, is why we have been so active in our study of this in the United States.

Hobbs (U.K.): The question has been raised concerning the competition between irradiation and freezing, and I think it has been said that we would not consider irradiation of frozen fish. This is precisely what we would propose to do in the United Kingdom. The process we are suggesting is a process which will, we hope, help the distribution of packaged fish through the supermarket chain. We are already doing marketing trials with packaged fish, unirradiated. This is sea-frozen fish. The shelf life we are giving it is four days from thawing

out to sale, and this is where we get back to this point of taste panel determination to spoilage. Four days at chill temperature is nowhere near unacceptable fish. Now if we irradiate this at 0.25 to 0.3 Mrad we can at least double the shelf life. If, therefore, we can use sea-frozen fish irradiated at a pasteurizing dose, maintain the temperature below 5°C, we can give the distribution and retail trade something like eight to 10 days and still have a good quality fish. This storage time would not be anywhere near the time that it would require for botulinum toxin to develop even if the temperature went up to 10 or 12°C. As regards irradiation of inshore fish, the work we have done indicates that it is not worthwhile irradiating fish more than six to eight days in ice. This is primarily the reason why we went initially for frozen fish, but perhaps it is worthwhile to consider, as well, irradiating inshore fish which in the United Kingdom is about two or three days in ice.

Liston (U.S.A.): This is interesting in that it introduces the concept of coupling irradiation and freezing in the order of freezing first and irradiation second. I believe there has also been some discussion of using irradiation to preserve the bacteriological quality, at least, of fish which could subsequently be frozen.

Massa (Italy): I would like to comment on van Meir's paper on the economic possibility of radiopasteurization of fish because I think this not only concerns fish in the United States, but is a topic of interest to all of us. I am considering the problem of application of ionizing radiation in the field of quarantine for the sanitation treatment of food, including fish, when it is contaminated with parasites or perhaps with food poisoning organisms. We must not leave the operation of irradiation plants only to private industries. In this particular application, we must consider the possibility that some governmental agency or some governmental body should be largely responsible for running the plant. In this sense, even if the economics are not very promising, they should be secondary to the public health aspects. This is particularly true if we devote more attention to the problem in developing countries where food-borne disease, including parasites, and viruses are a hazard not only to human beings but also to animals and plants. In view of these quarantine aspects, I think we must consider the possibility, in the economics of irradiation, that there be direct governmental interest. Perhaps public health or agriculture or whatever agency that is responsible for the problem of food hygiene and food control should run the plant directly. I also suggest that we must nave stronger international collaboration in this field, particularly in developing countries.

van Meir (U.S.A.): I agree that to implement the commercial application of radiopasteurization, government assistance will be needed and perhaps even public investment. However, I submit that if governments make the decision to invest in a commercial irradiator, they will make the decision on the basis of some kind of a cost benefit analysis. If the benefits do not cover the cost, the government likely will not make the investment. Governments face the same problem as private industry. They have limited resources relative to their alternatives.

Amano (Japan): To make the best use of irradiation facilities, one should consider other processes in addition to fish irradiation. Irradiation of seaweed, gelidium species, might be one I can suggest. Extraction of agar-agar with a good yield and a high jelly strength can be done effectively with the aid of irradiation.

Kreuzer (FAO): Wiesner suggested that a second irradiation treatment could be made on board fishing vessels during the return trip. To be economic a fishing vessel or factory ship must have a full load and should return to port loaded to the top. There will be no space to move stored fish backward and forward for a second irradiation treatment. Cost estimates of technological processes must be based on facts, gained from experience or pilot processing operations.

Rudolphi (Federal Republic of Germany): We should be warned against any overlooked weak spots in this new system. Somebody should be the *advocatus diaboli*. It would be, for instance, unfortunate for the other partners in the fish business if the newly gained shelf life is already used up in the first stages of the handling between catching and cooking.

Wiesner (Federal Republic of Germany): In reply to Rudolphi, I might mention three points. There is danger of too rapid re-infestation of irradiated fish through insufficient care in handling. Secondly, since irradiated fish may be stored somewhat longer, additional ice is required and this may add a little to the cost. Thirdly, apart from obtaining the necessary public licences, there will need to be a lot of publicity. There is a prejudice against irradiated foods in some European countries.

Advertisement Section

Cimco Ltd. 522
Danfoss A/S 523
Arthur J. Heighway Publications Ltd. 520-1
Fishing News (Books) Ltd. 524
Food and Agriculture Organization 526–7
Grenco N.V. 524
Jackstone Forster Ltd. 528
Nordischer Maschinenbau Rud. Baader 528
Pittsburgh Corning de Belgique, S.A. 525

We Help Fishermen of the World

Our task and pleasure is to help the fishermen of the world. We do this in two ways. First by our periodicals—Fishing News (weekly) serving the fishermen and fishing companies of Great Britain and West Europe with current news and special articles on new vessels, gear, equipment, processing and marketing measures; and Fishing News International (monthly) serving the world with quite the best all-round editorial service. Our readers are the makers of decisions in Governmental, scientific and operational circles. And they give us the highest paid-for circulation in this field.

Secondly, we help fishermen by issuing a steady series of books to provide basic reliable guidance on useful aspects of fishing operation.

Books already published are listed below. They are added to by some half dozen new titles each year. Their issue is announced through our journals and through a free 36-page booklet sent on request.

Each issue of Fishing News International gives current news reports on important trends in international fisheries.

Special surveys of fishing countries, their catches, ports, products or methods.

Technical reports describe methods in catching, processing, handling, resource and product research work, plant or packaging materials.

Ports and markets—catch trends and developments in equipment, transport, marketing.

In three years 1966–68 completion of over 1000 fishing vessels were reported with detailed descriptions of over 500. New gear and equipment fully covered.

FAO reports, meetings and exhibitions adequately reported.

Advertising support is outstanding. In one year alone 180 major firms used our columns.

Through our enquiry and reply service hundreds of inquiries were handled.

Subscription for all this superb service is

£3 10s. 0d. *per year*

New price list for 1969

Subject to change without notice

Automation in Merchant Ships	£5 15s. 0d.
Atlantic Ocean Fisheries	£4 10s. 0d.
British Freshwater Fishes	£1 11s. 6d.
Developments in Handling and Processing Fish	£1 5s. 0d.
Escape to Sea	£1 5s. 0d.
Farming the Edge of the Sea	£4 5s. 0d.
Fishing Boats of the World 1	£8 10s. 0d.
Fishing Boats of the World 2	£9 0s. 0d.
Fishing Boats of the World 3	£9 10s. 0d.
Fishing Boats and Equipment	£2 5s. 0d.
Fish Catching Methods of the World	£3 10s. 0d.
Fisheries Hydrography	£2 15s. 0d.
Fish in Nutrition	£7 10s. 0d.
Fishing with Electricity	£3 12s. 6d.
Freezing and Irradiation of Fish	£11 10s. 0d.
Handy Medical Guide for Seafarers limp cover	£1 0s. 0d.
case bound	£1 10s. 0d.
How to Make and Set Nets	£1 15s. 0d.
Introduction to Trawling	£1 0s. 0d.
Irish Salmon	12s. 6d.
Japan's World Success in Fishing	£3 5s. 0d.
Lobsters, Crabs and Crawfish	£1 7s. 0d.
Mechanization of Small Fishing Craft	£2 0s. 0d.
Modern Fishing Gear of the World 1	£8 10s. 0d.
Modern Fishing Gear of the World 2	£8 10s. 0d.
Modern Deep Sea Trawling Gear	£2 2s. 0d.
More Scottish Fishing Craft and their Work	£2 5s. 0d.
Multilingual Dictionary	£7 10s. 0s.
Refrigeration on Fishing Vessels	£2 12s. 6d.
The Seine Net: Its Origin, Evolution and Use	£4 5s. 0d.
Scottish Fishing Craft	£1 10s. 0d.
Ships' Gear	£7 10s. 0d.
Small Ships Radio Telephone Handbook 1969/70	£1 15s. 0d.
Sonar in Fisheries	£1 17s. 6d.
Stability and Trim	£1 10s. 0d.
The Fertile Sea	£2 15s. 0d.
The Lemon Sole	£1 5s. 0d.
The Stocks of Whales	£2 7s. 6d.
The Technology of Fish Utilization	£7 0s. 0d.
Testing the Freshness of Frozen Fish	£1 0s. 0d.
Trawlermen's Handbook	£2 0s. 0d.
Tuna: Distribution and Migration	£2 2s. 0d.
Underwater Observation Using Sonar	£2 0s. 0d.

36-page book list available free on request

Fishing News International

FISHING NEWS (Books) LTD

110 Fleet Street, London, EC4, ENGLAND

NEW BOOKS about FISHING

HANDY MEDICAL GUIDE for SEAFARERS

Dr. R. W. Scott, especially experienced in mining and seafaring accidents and illnesses, has compiled this work in order to give immediate guidance to those too far from medical aid.

In 15 chapters is covered examination and diagnosis of illness, treatment of wounds, head injuries, the digestive system, ear, nose and eye injuries, burns and fire hazards, cold and survival factors.

Amply illustrated.

Limp Cover £1. Hard case £1 10s. 0d. Postage 1s. 0d.

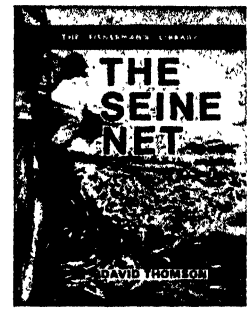
TUNA DISTRIBUTION AND MIGRATION

Tuna fishing companies and skippers need this book to achieve the most successful results. Author is a leading Japanese scientist who, appreciating the intimate relationship between currents, temperatures, seasonal movements and the presence of tuna, evolved the practices now used by Japanese skippers.

While a visiting scientist at Hawaii he was persuaded by the Director, J. C. Marr, to prepare this treatise which gives for the first time Japanese methods.

Twenty-three figures and six tables.

£2 2s. 0d. Postage 2s. 0d.



This volume on the "origin, evolution and use" of the seine net now used in important fisheries the world over, is based on practical experience plus scholarship. The author, of Scottish fishing stock, went to sea at 15, took his skipper's ticket at 21, broadened his experience in Africa and USSR, and is now a Professor at Rhode Island University, USA.

The volume is historically important as it includes hitherto unpublished facts and figures. It is also a practical text book on how to use the seine net successfully. It includes plans of many nets adapted to local circumstances.

Large pages, art paper, 212 pages, 144 photographs, diagrams and plans.

£4 5s. 0d. Postage 5s. 0d.

All books now available from
FISHING NEWS (BOOKS) LTD.,
110 Fleet St., London E.C.4.
(36 page booklist free on request)

The FERTILE SEA

Two widely known international scientists give here a fascinating explanation of the chains of life which provide the fisherman's harvest of fish. The work was commissioned by the Buckland Foundation Trustees but Dr. A. P. Orr died before he amplified his lectures into book form.

That task was ably completed by Dr. S. M. Marshall, herself a noted biologist. Of particular value are the illustrations and drawings of microscopic zooplankton and phytoplankton together with keys for identification. These are particularly useful to students and fishermen seeking fullest knowledge in their own field.

Seven chapters lead through the various chains of life to a final one on the production of fish and shellfish.

One hundred and forty-eight pages, 54 figures, special art section of 15 plates.

£2 15s. 0d. Postage 1s. 6d.

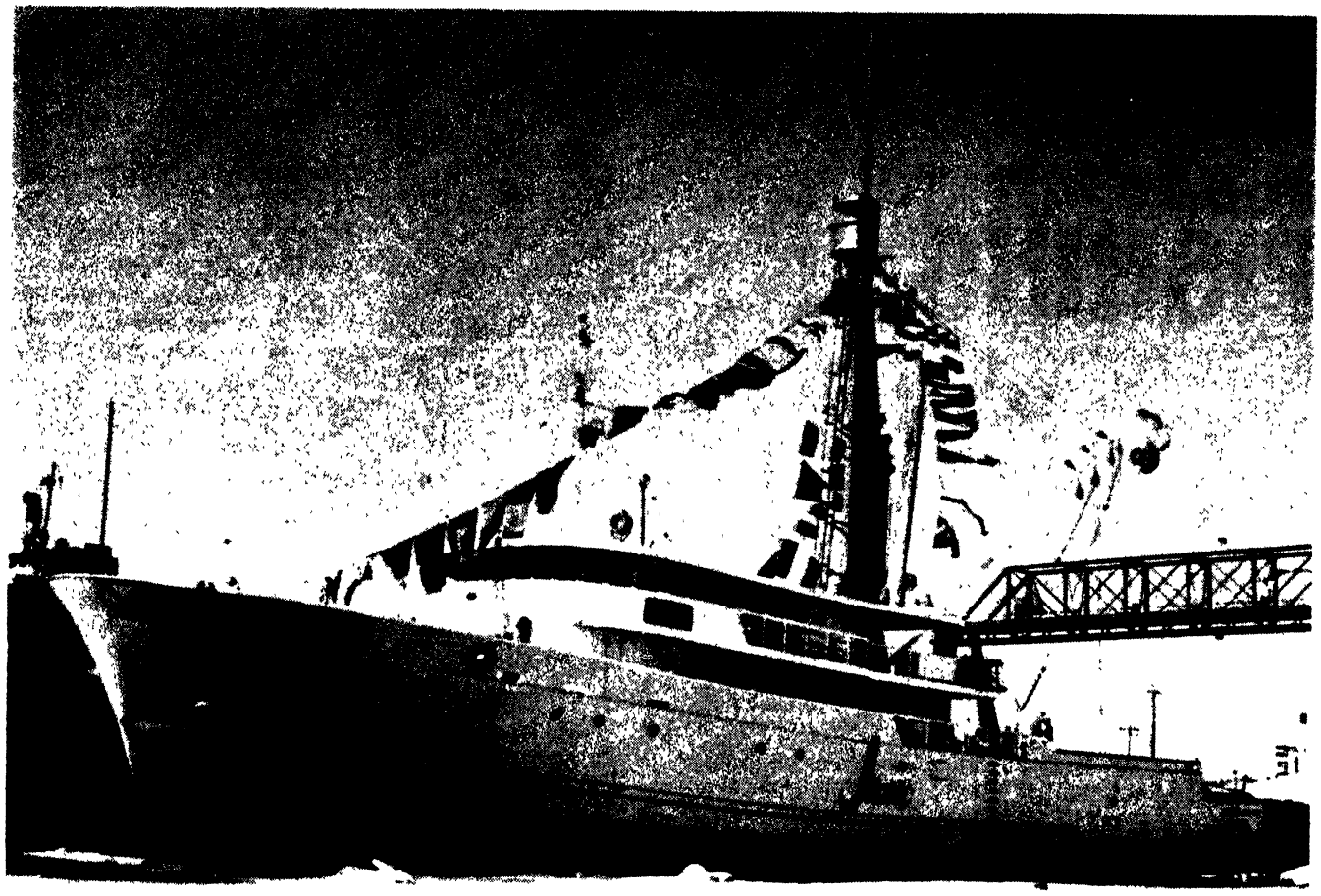
REFRIGERATION ON FISHING VESSELS

This book will command a world market wherever refrigeration is needed for securing best results for landings. Author, J. H. Merritt, Head of Torry Engineering Section, is a specialist on refrigeration.

The aim has been to present the fundamental principles and practices found by long experience in Britain, Canada, and USA and, in fact in all advanced fisheries, as necessary for successful and economical operation.

Seventeen plans and diagrams effectively illustrate the principles outlined. This is a thoroughly sound recommended work issued with the full approval and authority of the Department in charge of Torry Research Station. (148 pages).

£2 12s. 6d. Postage 2s. 6d.



Engineers: R T. Tamblyn & Partners Ltd

Built by. Canadian Vickers Ltd

"A ship built around a refrigeration system"

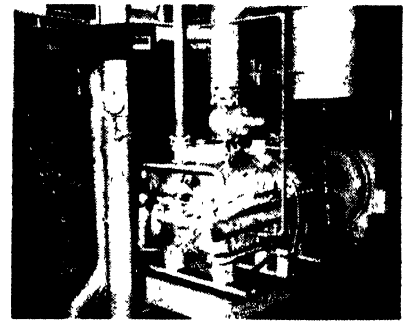
The "Atlantic-John Park", one of five similar vessels which will supply the new Tuna cannery of Canadian Tuna Company (1965) Limited, is an excellent example of how to use space. Built as a dual purpose fishing vessel, this 1,000 ton, 16,000 mile range vessel will revitalise Canada's possibilities in the world's fishing industry.

Large freezing and storage capacity

Four brine freezing tanks are located in the tween deck and will freeze a maximum of 100 tons per day to 0°F. When frozen, the fish are transferred from the tanks into the insulated cargo hold by means of a conveying belt system. The fish hold has a capacity of 900 tons and will be kept at —20°F.

Refrigeration plant

The refrigeration machinery consists of four identical York internally compounded compressors. Two are diesel driven and two are equipped with two-speed electric motor drives.



A new marine refrigeration installation? Modernization or overhaul? Contact the address below for more information.

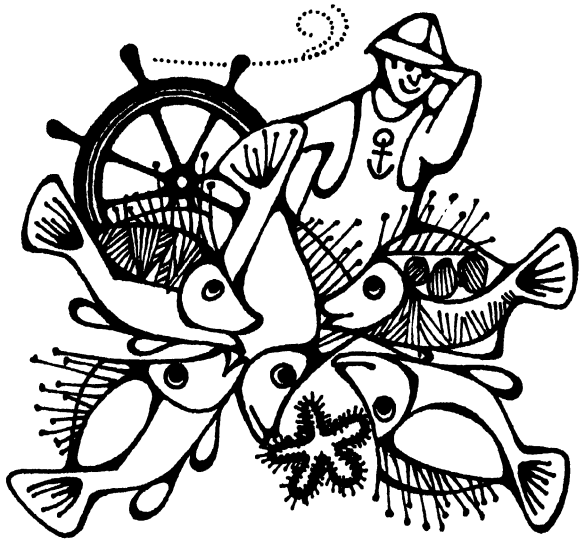
CIMCO LIMITED

THE NEW NAME OF CANADIAN ICE MACHINE CO LTD.

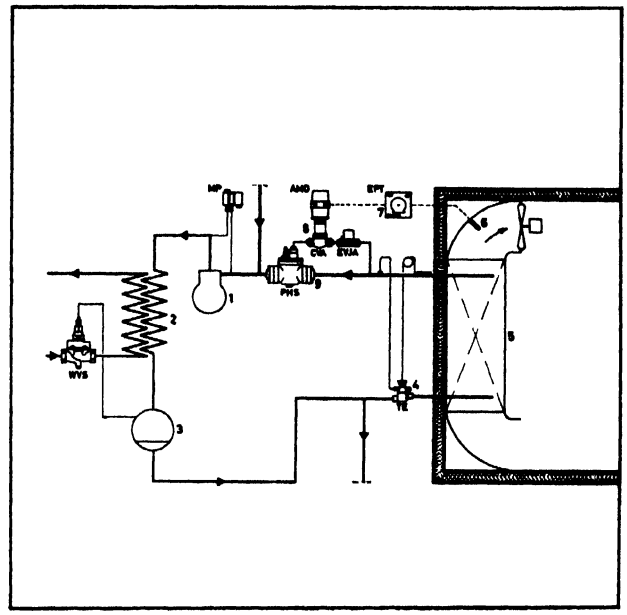
REFRIGERATION CONTRACTORS

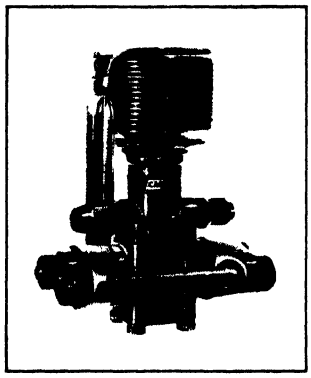
65 VILLIERS STREET, TORONTO 2, ONTARIO • 416/465-7581

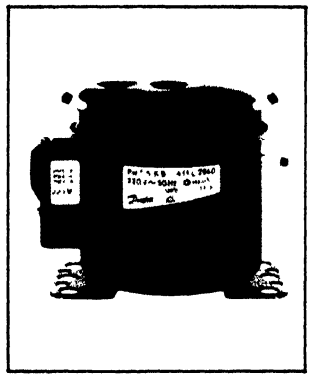
HALIFAX, MONTREAL, OTTAWA, TORONTO, LONDON, WINNIPEG, SASKATOON, CALGARY, EDMONTON, VANCOUVER

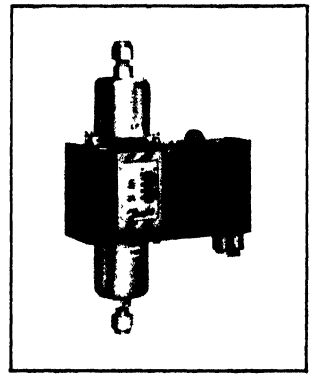


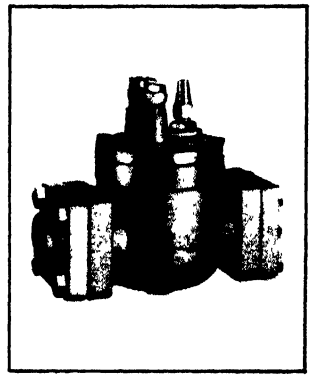
Example of ship refrigeration plant automated by the use of Danfoss automatic controls











Regulate with Danfoss

The Danfoss production range of refrigeration equipment includes automatic controls for commercial refrigerating plants, industrial refrigerating plants, air-conditioning plants, and an extensive range of hermetic compressors.
The Danfoss products are being developed all the time, and rigid quality control ensures a constant and high standard.
A world-wide sales and service organization is behind every Danfoss product – Danfoss has it all – make use of the obvious advantages. All automatic controls from one factory.

3491

Danfoss

NORDBORG • DENMARK

AUTOMATIC CONTROLS AND EQUIPMENT

GRENCO

hand in glove with fish refrigeration

This symbol represents refrigeration installation at its best. Grenco has extensive international experience, a thorough knowledge of all modern methods of freezing designed to keep your catch in the best possible condition. It has its own installation research aimed at the development and construction of the most efficient operation of freezing plants backed by a team of specialists acquainted with all the biological problems that arise when deep freezing fish. Add to this a rapid, international service organisation and you have... Grenco.
Grenco N.V. Head Office: Hertogenbosch - Holland. P.O.B. 304, Telex 50147, Subsidiaries in Brussels, Old Woking (Surrey), Hamburg, Madrid, Vigo, Istanbul, Cape Town, and five in The Netherlands.

Basic books from FAO congresses

Over the years we have been privileged to help the fishing industry by publishing books from many important FAO Conferences, namely:

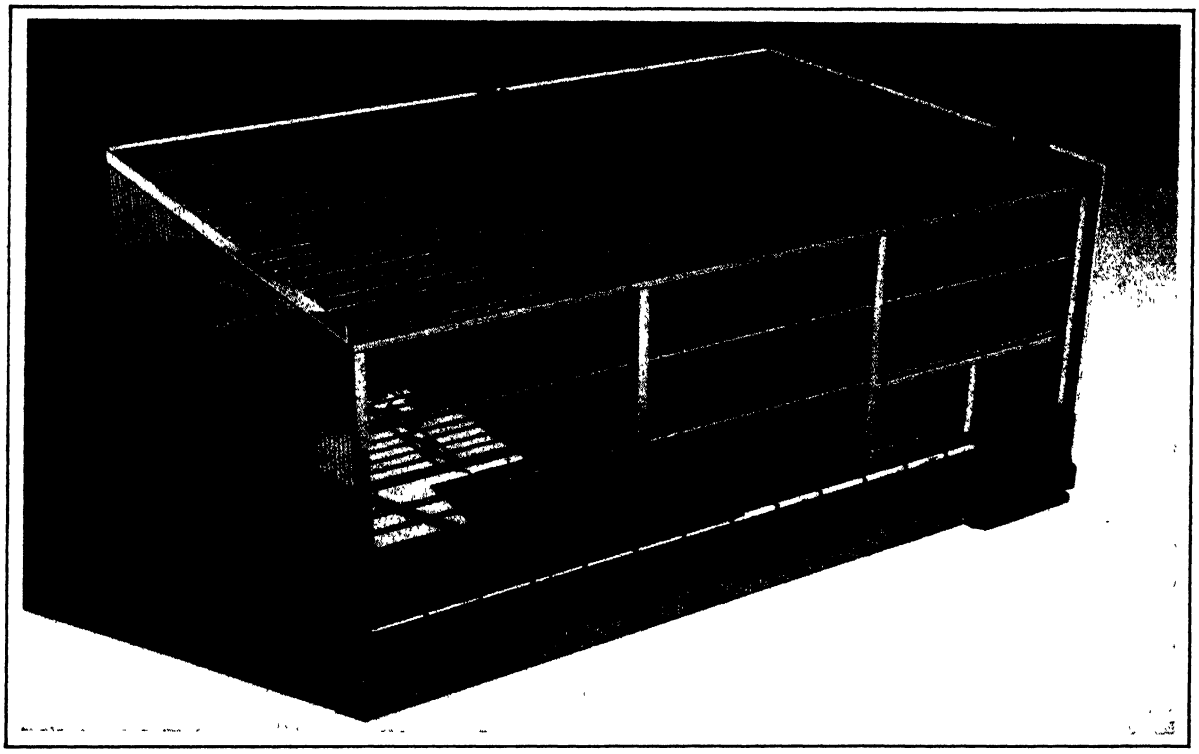
1. **Fishing Boats of the World 1.** 70 major papers plus practical contributions in discussion.
2. **Modern Fishing Gear of the World.** 110 major papers covering 13 principal sections of interest.
3. **Fishing Boats of the World 2.** 55 papers with outstanding additional contributions. Four main sections.
4. **Fish in Nutrition.** 70 papers in five sections on all aspects of human utilization.
5. **Modern Fishing Gear of the World 2.** 157 authors and contributors covered 16 principal sections.
6. **Technology of Fish Utilization.** 112 authors and contributors, 6 sections summarized, available processes and methods.
7. **Fishing Boats of the World 3.** 32 outstanding papers in 6 sections completed a trio on boats of over 2,000,000 words and 2,500 figures.
8. **Fishing with Electricity.** Some 16 European experts integrated available knowledge and techniques. In four parts.
9. **Freezing and Irradiation of Fish.** 79 authors of outstanding merit cover in six sections all aspects of this subject.
10. **Fishing Ports and Markets** (now in preparation). Planned to cover distribution and effective marketing.

Totalling about 7,000 pages, over 6,000,000 words, nearly 5,000 figures, these books constitute a gold mine of knowledge and technology. We are happy to have served FAO and the industry in making this wealth available to those concerned.

FISHING NEWS (BOOKS) LTD.

110 Fleet Street London EC4

Here's the fast, easy way to build a cold storage warehouse



- **build a steel frame**
- **cover it with FOAMGLAS® cellular glass insulation**
- **add a thin finish for appearance**

FOAMGLAS®
CELLULAR GLASS INSULATION

It's called the Black Box technique. In this system, FOAMGLAS is part of the actual structure.

Here's how you can use it.

Walls : Free standing FOAMGLAS walls require only a steel frame and a thin outside finish. Because it is water and vaporproof, FOAMGLAS is its own vapor barrier (Diffusion resistance factor for water vapor : ∞).

Roof : Simply apply FOAMGLAS within a system of T-irons and the insulation becomes the deck.

Floor : FOAMGLAS is strong enough to carry even the load of the columns of the steel structure.
And because FOAMGLAS is incombustible, it reduces fire hazards, too.
For more information about FOAMGLAS, contact Pittsburgh Corning de Belgique, S.A., 19 Avenue des Nénuphars, Brussels 16. Tel. 73 40 80. Distributors in Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Greece, Holland, Italy, Norway, Portugal, Spain, Sweden, Switzerland and Turkey.

® Registered trademarks in the U.S.A. and other countries.

PITTSBURGH PC® CORNING DE BELGIQUE S.A

FAO YEARBOOK OF FISHERY STATISTICS
WORLD FISHERIES ABSTRACTS
FISHERIES MISCELLANEOUS

FAO YEARBOOK OF FISHERIES STATISTICS **Trilingual** **First published in 1948**

The most important internationally-published source of world-wide statistical tabulations covering, annually, catches and landings, disposition of catches, and production, imports and exports of preserved and processed fishery commodities. Usually published within 10 months of the close of the last calendar year covered. The YEARBOOK data for many countries appear months before their national release.

Until the end of 1963, the **Production and Fishing Craft** volume appeared annually and the **International Trade** volume biennially. Since 1964, two volumes have appeared annually. The latest volumes are:

Volume 21	**Fishery Commodities**	1965 data	**$7.00 or 35s. or FF24,50**
Volume 22	**Catches and Landings**	1966 data	**$5.50 or 27s. 6d. or FF19,25**
Volume 23	**Fishery Commodities**	1966 data	**$8.00 or 64s. or FF40,00**
Volume 24	**Catches and Landings**	1967 data	**$6.00 or 48s. or FF30,00**
Volume 25	**Fishery Commodities**	1967 data	**$8.00 or 64s. or FF40,00**

The YEARBOOK is supplemented by a trilingual series of **Bulletins of Fishery Statistics.** Numbers are issued from time to time and limited supplies are available from the DISTRIBUTION AND SALES SECTION, FOOD AND AGRICULTURE ORGANIZATION, VIA DELLE TERME DI CARACALLA, 00100 ROME, ITALY.

FAO WORLD FISHERIES ABSTRACTS

English, French and Spanish editions Single issue: **$1.25 or 10s. or FF6,25** Annual subscription: **$4.00 or 32s. or FF20,00**

A quarterly review of fisheries technological literature. Subjects include fishing boats and methods, fish handling, processing, analysis, chemical composition, nutritive value and quality control. The average issue contains about 140 references, abstracted on 69 cards convenient for filing (3 × 5 in. or 76 × 127 mm.), plus two pages of technological notes. Abstracts can be filed alphabetically by author, subject, UDC and FWS code systems. To assist the reader to obtain copies of references, each reference abstracted carries, where possible, the current address of the author. **Note:** Replacement of the **World Fisheries Abstracts** by a quarterly review may be considered in the future.

FAO FISHERIES MISCELLANEOUS

Fishermen and the Weather

by K. Terada (in preparation) **English, French and Spanish editions** **Price: to be determined**

Intended to help the fishermen to understand the principles and value of meteorology in their profession, this publication is an elementary guide in how to make meteorological observations and to forecast the weather at sea. It also instructs how to report weather data from fishing vessels, how to make use of weather information and how to produce a weather bulletin. Illustrations and charts accompany the text.

FAO Fisheries Index

The Fisheries Index covers publications and documents produced by the Department of Fisheries from 1945 to 1966 with subsequent six-monthly supplements. The biographical list contains some 2,600 entries from which the analytic index and the author index have been derived.

Price: $5.00 or 40s. or FF25,00

For a free copy of the complete **Catalogue of FAO Publications** write to: DISTRIBUTION AND SALES SECTION, FOOD AND AGRICULTURE ORGANIZATION, VIA DELLE TERME DI CARACALLA, 00100 ROME, ITALY.

FAO FISHERY STUDIES

A series of monographs on selected topics of importance in English, French and Spanish editions

No. 10 COSTS AND EARNINGS INVESTIGATIONS OF PRIMARY FISHING ENTERPRISES

by A. E. Ovenden, 1961, 60 pp. **Price: $0.75 or 3s. 9d. or FF2,70**

A study of the concepts and definitions of primary fishing economies, with definition of terms used in costs and earning studies with application to practical work.

No. 11 FINANCIAL ASSISTANCE POLICIES AND ADMINISTRATIONS FOR FISHERY INDUSTRIES

by E. S. Holliman, 1962, 121 pp. **Price: $1.00 or 5s. or FF3,50**

The third FAO publication on financial aid schemes in fishery development based on discussion and papers contributed to the FAO Technical Meeting on Credit for Fishery Industries, Paris 1960. Drawing on his experience as Assistant Chief Executive of the White Fish Authority, Mr. Holliman covers many of the finer points of administrative decision-making in fishery industries.

No. 12 HANDBOOK OF MUTUAL INSURANCE SYSTEMS FOR COMMERCIAL FISHING VESSELS AND GEAR

by C. A. Theodore, 1966, 117 pp. **Price: $2.00 or 10s. or FF7,00**

Intended for countries where the need for insurance has increased with the progress of fishing development, this study gives the practical knowledge and experiences of countries where mutual insurance systems have been successfully established and operated for many years.

FAO MANUALS IN FISHERIES SCIENCE

A series of practical guides for fishery workers, describing techniques and plans in fisheries science

No. 1 MANUAL OF METHODS OF FISHERIES BIOLOGY

by T. Laevastu, 117 pp. **English, French and Spanish editions** **Price: $5.00 or 25s. or FF17,50**

This volume provides a useful description of the techniques of observations and measurement of fisheries research. The chapters cover: Planning — Recording and Reporting Field Work — Observations on the Physical and Chemical Environment — Observations on Plankton — Benthos — Nekton and Sea Birds — Research on Fish Stocks — Field Observations on Fishing Operations.

No. 3 MANUAL OF SAMPLING AND STATISTICAL METHODS FOR FISHERIES BIOLOGY
Part I: Sampling Methods

by J. A. Gulland, 1966, 87 pp. **English, French and Spanish editions** **Price: $2.00 or 10s. or FF7,00**

Outlines methods of developing good sampling systems for the factors of major interest in fisheries biological research. Four sections deal with: General Statistics — Theory of Sampling — Sampling the Catch — Sampling the Population. A bibliography is included.

Part II: Statistical Methods (in preparation)

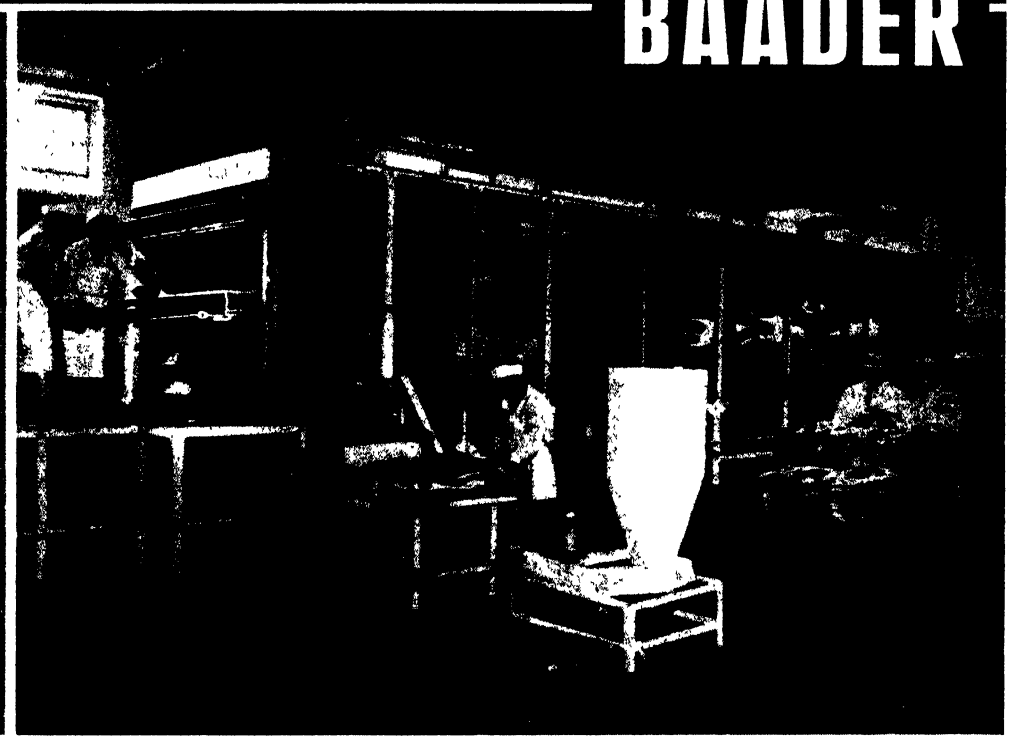
No. 4 MANUAL OF METHODS FOR FISH STOCK ASSESSMENT Part I: Fish Population Analysis

by J. A. Gulland, 136 pp. (scheduled for publication in 1969) **English, French and Spanish editions** **Price: to be determined**

Mainly concerned with the long-term effect of fishing on stocks and catches, this manual deals with the problems of estimating parameters (growth, mortality, recruitment, tagging, selection) and the use of these estimates as bases for determination of the total yield and the possibilities of expansion.

The following parts are in preparation: Part II: Tables of Yield Functions; Part III: Selectivity of Fishing Gears; Part IV: Report on Marking; Part V: Direct Assessment.

BAADER



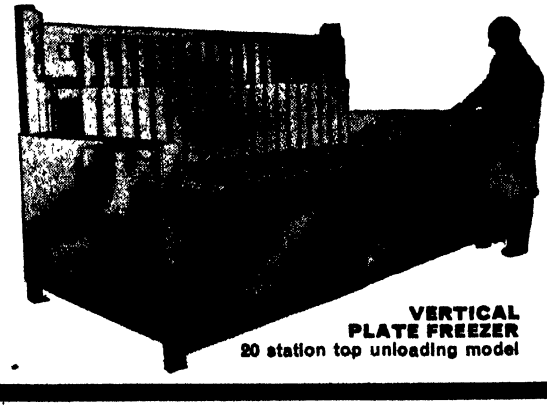
NORDISCHER MASCHINENBAU RUD. BAADER

THE INTERNATIONAL NAME FOR FREEZING EQUIPMENT

JACKSTONE PLATE FREEZERS

incorporate direct conduction aluminium alloy or standard steel freezing plates to suit your requirements. Vertical and horizontal plate freezers with capacities ranging from 200 lbs. to 4,000 lbs/hour are available for freezing whole fish, fish fillets, fish sticks, prawns, shrimps.

JACKSTONE FROSTER



VERTICAL PLATE FREEZER
20 station top unloading model

Head Office · West Side · Royal Dock · Grimsby · England · Tel : Grimsby 5308 · Telegrams : JACKSTONE GRIMSBY · Telex 52408

No: 11322